Environmental Science

A Study of Interrelationships

SIXTEENTH EDITION

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Mc Graw Hill

ENVIRONMENTAL SCIENCE, SIXTEENTH EDITION

This book is printed on acid-free paper.

1 2 3 4 5 6 7 8 9 LWI 24 23 22 21

ISBN 978-1-260-72223-9 (bound edition)
MHID 1-260-72223-6 (bound edition)

ISBN 978-1-265-09613-7 ((loose-leaf edition))
MHID 1-265-09613-9 ((loose-leaf edition))

Portfolio Manager: *Jodi Rhomberg*
Product Developers: *Theresa Collins*
Marketing Manager: *Bitney Ross*
Content Project Managers: *Jessica Portz and Rachael Hillebrand*
Buyer: *Sandy Ludovissy*
Designer: *David W. Hash*
Content Licensing Specialist: *Beth Cray*
Cover Image: *Yellow Dog Productions/Digital Vision/Getty Images*
Compositor: *SPi Global*

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Library of Congress Cataloging-in-Publication Data

Names: Enger, Eldon D., author. | Smith, Bradley F., author.
Title: Environmental science : a study of interrelationships / Eldon D. Enger, Delta College, Bradley F. Smith, Western Washington University.
Description: Sixteenth edition. | Dubuque : McGraw-Hill Education, [2022] | Includes bibliographical references and index.
Identifiers: LCCN 2020042083 | ISBN 9781260722239 (hardcover)
Subjects: LCSH: Environmental sciences–Textbooks.
Classification: LCC GE105 .E54 2022 | DDC 304.2–dc23
LC record available at https://lccn.loc.gov/2020042083

mheducation.com/highered

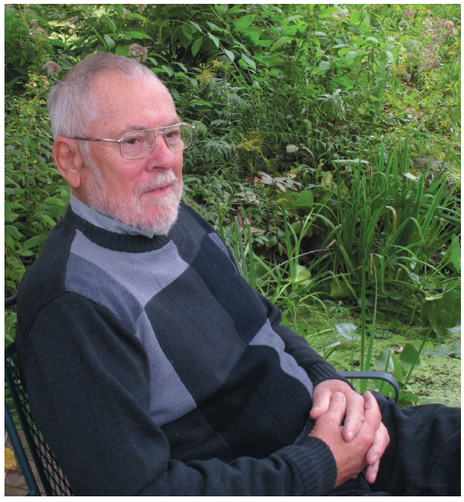
To Judy, my wife and friend,
for sharing life's adventures

ELDON ENGER

For my lovely wife Daria,
who has survived 45 years with me
and 16 editions.

BRAD SMITH

About the Authors



Courtesy of Eldon D. Enger

Eldon D. Enger is an emeritus professor of biology at Delta College, a community college near Saginaw, Michigan. He received his B.A. and M.S. degrees from the University of Michigan. Professor Enger has over 30 years of teaching experience, during which he has taught biology, zoology, environmental science, and several other courses. He has been very active in curriculum and course development. A major curriculum contribution was the development of an environmental technician curriculum and the courses that support it. He was also involved in the development of learning community courses in stream ecology, winter ecology, and plant identification. Each of these courses involved students in weekend-long experiences in the outdoors that paired environmental education with physical activity—stream ecology and canoeing, winter ecology and cross-country skiing, and plant identification with backpacking.

Professor Enger is an advocate for variety in teaching methodology. He feels that if students are provided with varied experiences, they are more likely to learn. In addition to the standard textbook assignments, lectures, and laboratory activities, his classes included writing assignments, student presentation of lecture material, debates by students on controversial issues, field experiences, individual student projects, and discussions of local examples and relevant current events. Textbooks are very valuable for presenting content, especially if they contain accurate, informative drawings and visual examples. Lectures are best used to help students see themes and make connections, and laboratory activities provide important hands-on activities.

Professor Enger received the Bergstein Award for Teaching Excellence and the Scholarly Achievement Award from Delta College and was selected as a Fulbright Exchange Teacher twice—to Australia and Scotland. He has participated as a volunteer in several Earthwatch Research Programs. These include studying the behavior of a bird known as the long-tailed manakin in Costa Rica, participating in a study to assess the possibility of reintroducing endangered marsupials from off-shore islands to mainland Australia, helping with efforts to protect the nesting beaches of the leatherback turtle in Costa Rica, and assisting with on-going research on the sustainable use of fish, wildlife, and forest resources in the Amazon Basin in Peru. He also participated in a People to People program, which involved an exchange of ideas between U.S. and South African environmental professionals.

He has traveled extensively, which has allowed him first-hand experience with coral reefs, ocean coasts, savannas, mangrove swamps, tundra, prairies, tropical rainforests, cloud forests, deserts, temperate rainforests, coniferous forests, deciduous forests, and many other special ecosystems. These experiences have provided opportunities to observe the causes and consequences of many environmental problems from a broad social and scientific perspective.

He volunteers at a local nature center, land conservancy, and Habitat for Humanity affiliate. Since 2005, he and his wife have spent a month each year with other volunteers from their church repairing houses damaged by tornados, floods, and hurricanes throughout the United States.

Professor Enger and his wife Judy have two married sons and four grandchildren. He enjoys a variety of outdoor pursuits such as cross-country skiing, snowshoeing, hiking, kayaking, hunting, fishing, camping, and gardening. Other interests include reading a wide variety of periodicals, beekeeping, singing in a church choir, picking wild berries, and preserving garden produce.

Bradley F. Smith is the Dean Emeritus of Western Washington University in Bellingham, Washington, having served as Dean from 1994 to 2012. Prior to assuming the position as Dean in 1994, he served as the first Director of the Office of Environmental Education for the U.S. Environmental Protection Agency in Washington, D.C., from 1991 to 1994. Dean Smith also served as the Acting President of the National Environmental Education and Training Foundation in Washington, D.C., and as a Special Assistant to the EPA Administrator.

Courtesy of Bradley F. Smith

Before moving to Washington, D.C., Dean Smith was a professor of political science and environmental studies for 15 years, and the executive director of an environmental education center and nature refuge for five years.

Dean Smith has considerable international experience. He was a Fulbright Exchange Teacher to England and worked as a research associate for Environment Canada in New Brunswick. He is a frequent speaker on environmental issues worldwide and serves on the International Scholars Program for the U.S. Information Agency. He also served as a U.S. representative on the Tri-Lateral Commission on environmental education with Canada and Mexico. He was awarded a NATO Fellowship to study the environmental problems associated with the closure of former Soviet military bases in Eastern Europe. He is a Fellow of the Royal Institute of Environmental Science in the U.K.

Dean Smith is a commissioner of the Washington State Fish and Wildlife Commission (served as Chair from 2015–2020). He is the chair of the board of trustees for Bellingham Technical College (BTC). BTC operates a fish hatchery as part of their aquaculture program that produces 5 million salmon a year for Puget Sound. Dean Smith is a member or the Governors Orca Whale Task Force. He also serves on the North Pacific Research Board and on the Bering Sea Fisheries Advisory Board and on the board of Washington Sea Grant. Previously, he served as chair of the Washington State Sustainability Council, as president of the Council of Environmental Deans and Directors, as a Trustee of the National Environmental Education Foundation, and as a member of the National Advisory Council for Environmental Policy and Technology for the USEPA. He also served on President Bill Clinton's council for Sustainable Development (Education Task Force). From 2004 to 2013 he served on the Steering Committee of the Commission for Education and Communication for the International Union for the Conservation of Nature (IUCN) in Gland, Switzerland.

Dean Smith holds a Ph.D. from the School of Natural Resources and the Environment at the University of Michigan.

Dean Smith and his wife, Daria, live along the shores of Puget Sound in Bellingham, Washington, and spend part of the summer at their summer home on the shores of Lake Huron in the Upper Peninsula of Michigan. He has two married grown children and two grandchildren, and is an avid outdoor enthusiast.

Brief Contents

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Preface

The Role of Environmental Science in Society

We live in a time of great change and challenge. Our species has profoundly altered the Earth. Our use of fossil fuels to provide energy is altering climate, our use of Earth's soil resources to feed ourselves results in extinctions, overexploitation of fish populations has resulted in the population declines of many marine species, and freshwater resources are becoming scarce. At the same time, we see significant improvement in other indicators. Energy-efficient and alternative energy technologies are becoming mainstream, population growth is beginning to slow, air and water pollution problems are being addressed in many parts of the world, and issues of biodiversity loss, climate change, and human health are beginning to be addressed on a worldwide basis.

However, there are still major challenges, and there are additional opportunities to lighten our impact on Earth. Understanding the fundamental principles that describe how the Earth's systems work is necessary knowledge for everyone, not just scientists who study these systems. It is particularly important for political, industrial, and business leaders because the political, technical, and economic decisions they make affect the Earth.

Why "A Study of Interrelationships"?

Environmental science is an interdisciplinary field. Because environmental problems occur as a result of the interaction between humans and the natural world, we must include both scientific and social aspects when we seek solutions to environmental problems. Therefore, the central theme of this book is interrelatedness. It is important to have a historical perspective, to appreciate economic and political realities, to recognize the role of different social experiences and ethical backgrounds, and to integrate these with the science that describes the natural world and how we affect it. *Environmental Science: A Study of Interrelationships* incorporates all of these sources of information when discussing any environmental issue.

Environmental science is also a global science. While some environmental problems may be local in nature—pollution of a river, cutting down a forest, or changing the flow of a river for irrigation—other problems are truly global—climate change, overfishing of the oceans, or loss of biodiversity. In addition, individual local events often add together to cause a worldwide problem—the actions of farmers in China or Africa can result in dust storms that affect the entire world, or the individual consumption of energy from fossil fuels increases carbon dioxide concentrations in the Earth's atmosphere. Therefore, another aspect of the interrelationships theme of this text is to purposely include features that highlight problems, issues, and solutions involving a variety of cultures.

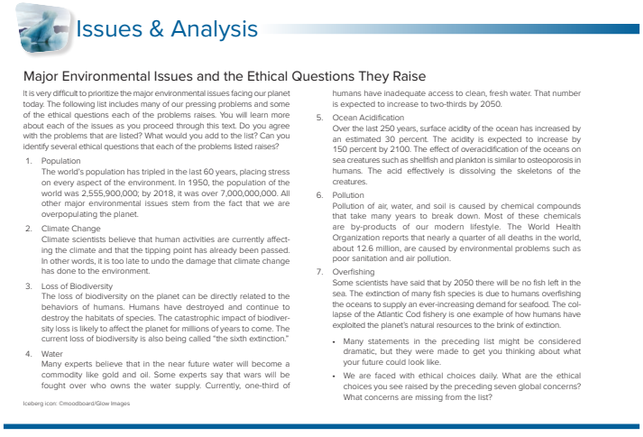
This text has been translated and published in Spanish, Chinese, and Korean. Therefore, students in Santiago, Shanghai, Seoul, or Seattle are learning the "hows and whys" involved in thinking and acting sustainably. At the end of the day, we all share the same air, water, and one not-so-big planet. It's important for all of us to make it last.

What Makes This Text Unique?

We present a balanced view of issues, diligently avoiding personal biases and fashionable philosophies.

It is not the purpose of this textbook to tell readers what to think. Rather, our goal is to provide access to information and the conceptual framework needed to understand complex issues so that readers can comprehend the nature of environmental problems and formulate their own views. Two features of the text encourage readers to think about issues and formulate their own thoughts:

- The **Issues & Analysis** feature at the end of each chapter presents real-world, current issues and provides questions that prompt students to think about the complex social, political, and scientific interactions involved.



Issues & Analysis

Major Environmental Issues and the Ethical Questions They Raise

It is very difficult to prioritize the major environmental issues facing our planet today. The following list includes many of our pressing problems and some of the ethical questions each of the problems raises. You will learn more about each of the issues as you proceed through this text. Do you agree with the problems that are listed? What would you add to the list? Can you identify several ethical questions that each of the problems listed raises?

1. Population
   The world's population has tripled in the last 60 years, placing stress on every aspect of the environment. In 1950, the population of the world was 2,555,900,000; by 2018, it was over 7,000,000,000. All other major environmental issues stem from the fact that we are overpopulating the planet.
2. Climate Change
   Climate scientists believe that human activities are currently affecting the climate and that the tipping point has already been passed. In other words, it is too late to undo the damage that climate change has done to the environment.
3. Loss of Biodiversity
   The loss of biodiversity on the planet can be directly related to the behaviors of humans. Humans have destroyed and continue to destroy the habitats of species. The catastrophic impact of biodiversity loss is likely to affect the planet for millions of years to come. The current loss of biodiversity is also being called "the sixth extinction."
4. Water
   Many experts believe that in the near future water will become a commodity like gold and oil. Some experts say that wars will be fought over who owns the water supply. Currently, one-third of humans have inadequate access to clean, fresh water. That number is expected to increase to two-thirds by 2050.
5. Ocean Acidification
   Over the last 250 years, surface acidity of the ocean has increased by an estimated 30 percent. The acidity is expected to increase by 150 percent by 2100. The effect of overacidification of the oceans on sea creatures such as shellfish and plankton is similar to osteoporosis in humans. The acid effectively is dissolving the skeletons of the creatures.
6. Pollution
   Pollution of air, water, and soil is caused by chemical compounds that take many years to break down. Most of these chemicals are by-products of our modern lifestyle. The World Health Organization reports that nearly a quarter of all deaths in the world, about 12.6 million, are caused by environmental problems such as poor sanitation and air pollution.
7. Overfishing
   Some scientists have said that by 2050 there will be no fish left in the sea. The extinction of many fish species is due to humans overfishing the oceans to supply an ever-increasing demand for seafood. The collapse of the Atlantic Cod fishery is one example of how humans have exploited the planet's natural resources to the brink of extinction.

- Many statements in the preceding list might be considered dramatic, but they were made to get you thinking about what your future could look like.
- We are faced with ethical choices daily. What are the ethical choices you see raised by the preceding seven global concerns? What concerns are missing from the list?

Iceberg icon: Cmoodboard/Glow Images

- The **What's Your Take?** feature found in each chapter asks students to take a stand on a particular issue and develop arguments to support their position, helping students develop and enhance their critical thinking skills.

What's Your Take?

The grizzly bear (*Ursus arctos horribilis*) has been receiving federal protection under the U.S. Endangered Species Act for over 30 years. The federal government has now proposed removing that protection on the basis of increasing numbers of bears in the Greater Yellowstone ecosystem and elsewhere. There is considerable disagreement among conservation biologists about how many bears are needed for the species to be "recovered." When a species is delisted, management is handed over to individual states. If it proposes an acceptable plan, a state may introduce a management plan that includes the hunting of the previously listed species. What kind of ethic underlies the Endangered Species Act? What kind of ethic underlies a management plan that includes hunting? Develop an ethical argument for or against the delisting of the grizzly bear.

Plant icon: ©Bear Dance Studios/Mark Dierker

We recognize that environmental problems are global in nature.

Three features of the text support this concern:

- Throughout the text, the authors have made a point to use **examples** from around the world as well as those from North America.
- Many of the boxed readings—**Focus On; Going Green; Science, Politics, & Policy;** and **Issues & Analysis**—are selected to provide a global flavor to the basic discussion in the text.

Focus On

Refugees—Involuntary Migrants

Refugees are involuntary migrants who flee their home countries because they fear persecution, war, or violence. It is also possible for persons to leave their home country because of natural disasters (drought, floods, etc.) that endanger their lives. Refugees are essentially international migrants who are seeking a safe place to live. According to the Office of the United Nations High Commissioner for Refugees (UNHCR), there were about 30 million refugees in the world at the end of 2019. Over half of them were from Afghanistan, Syria, and South Sudan, where war caused people to flee their home country.

When refugees cross borders, they have limited rights and protections because they are not citizens of the countries they enter. While most host countries recognize a humanitarian responsibility to help these people, the refugees are a significant social and economic burden. After all, refugees are generally poor, have not paid taxes to the host country, and are unlikely to be able to pay for services. Thus governments seek to control the entry of refugees and may restrict their movement, require settlement in refugee camps, and limit their access to health care, education, and other services.

The influx of a large number of people disrupts the local social structure of the host country. Any funding that is shifted to helping refugees reduces the amount of money available to fund programs for legal citizens. In addition, if refugees remain in an area, they will try to find jobs to earn money. Others may beg or steal. One of the outcomes of this tension between local citizens and refugees is the development of nationalistic or anti-immigrant groups among the host countries' citizens.

A sign from a demonstration in London, England October 2016
Rachel La Corte/AP Images

A camp in Turkey for Syrian refugees.
SOPA Images/Getty Images

Butterfly icon: ©Kris Bradley/flickr RF/Getty Images

We recognize that many environmental issues involve complex social, economic, and cultural aspects.

- The first three chapters focus on the underlying social, economic, health, and ethical aspects involved in understanding how people view environmental issues.
- The **Science, Politics, & Policy feature** shows how the scientific understanding of environmental problems is filtered through the lens of social and political goals to determine policy.
- Critical Thinking questions appear at the end of each chapter and require students to evaluate information, recognize bias, characterize the assumptions behind arguments, and organize information.

Science, Politics, & Policy

A History of Mercury Regulations

Science Facts

Mercury is a metal that is liquid at room temperature. It has been known to be toxic for centuries. However, when mercury enters aquatic ecosystems it can be converted to methylmercury by the action of bacteria. The methylmercury becomes concentrated in aquatic food chains and becomes a human health problem when certain species of fish are eaten by humans. The toxic effects of methylmercury have been known since the 1930s. Since methylmercury impairs brain development, fetuses, infants, and children are particularly susceptible. Because of the level of methylmercury and other toxic materials in fish, every state has advisories against eating certain kinds of fish from certain locations.

Because of the known health effects of elemental mercury and methylmercury, the EPA successfully regulated several of the major sources of mercury emissions such as cement plants and those industries that use mercury in their manufacturing processes. The primary remaining source of mercury in the environment is the stack gases from power plants that burn coal or oil. Mercury from power plants is released into the atmosphere and enters watersheds, where it is converted to methylmercury and becomes incorporated into the bodies of organisms.

Politics and Court Actions

The *George W. Bush administration* (2001–2009) in essence allowed power plants to be exempt from the Clean Air Act, which enabled power plants to avoid the cost of retrofitting their equipment to reduce mercury emissions. In 2008, a lawsuit was filed by several environmental organizations in the U.S. Circuit Court of Appeals in Washington, D.C. The appeals court overturned the Bush administration's mercury regulations and instructed the EPA to come up with a new rule. In 2009, an electric power industry group, Utility Air Regulatory Group, asked the Supreme Court to review the ruling by the appeals court, arguing that the Bush administration had legally decided not to regulate power plants under the Clean Air Act. The Supreme Court denied the request.

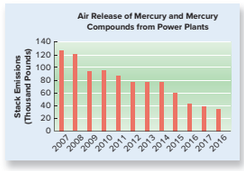
During the Obama administration (2009-2017) there were several regulatory and court actions. In December 2011, in response to the appeals court order to produce a new rule on mercury releases from power plants, the EPA published the Mercury and Air Toxics Standards (MATS) rule . MATS set a limit on the amount of mercury that power plants could release. Power plants were given four years in which to comply with the ruling. The rule would have ultimately reduced mercury emissions by 90 percent. Because there are several kinds of power plants that use different kinds of coal and other fuels, the setting of rules was a complicated process. In general, new plants must meet much more stringent requirements than existing plants.

In 2015, as a result of a lawsuit by Michigan and 20 other states and industry groups, the Supreme Court ruled 5 to 4 that the EPA should have considered the cost to industry of implementing the rule. The Washington D.C. circuit court reviewed the Supreme Court's ruling and decided that the EPA did not need to stop enforcement of the MATS rule while they completed the cost-benefit analysis. The states appealed the circuit court's ruling to the Supreme Court. In March 2016, Chief Justice John Roberts rejected a request to stay the Mercury and Air Toxic Standards rule. So the EPA could proceed with its enforcement actions while it conducted its investigations of the cost of implementing the rule. *The Trump administration began in* 2017. President Trump had promised more jobs in the coal industry, and less regulation on industry. In December 2018, in response to the Supreme Court ruling that the cost to industry should have been considered when the MATS rule was established, the EPA determined that the cost to industry was greater than the value of the health benefits of reducing mercury in the environment. Therefore, it was not "appropriate and necessary" to regulate mercury emissions from power plants. By 2020, the rule had not been finalized.

Emissions from coal-fired power plants are the major source of mercury in the environment.
Larry Lee Photography/Getty Images

Power Industry Reaction

Despite years of political maneuvering and court challenges, there is still no clear policy on mercury releases from power plants. However, the power industry has reacted to the availability of natural gas and the MATS rule by cancelling plans to build new coal-fired power plants and by shutting down many older (more polluting) coal-fired plants. Between 2010 and 2018 the amount of electricity generated by coal-fired power plants declined by 38 percent as many coal-fired plants were shut down. This resulted in a reduction in the demand for coal. Between 2013 and 2019, coal production fell by nearly 25 percent, and thousands of jobs were lost as several coal companies filed for bankruptcy. However, there is a silver lining. Throughout the years this issue has been fermenting, the actual mercury emissions from power plants have fallen by 70 percent, primarily because of the reduction in the number of coal-fired power plants. (See graph.)



Rock icon: ©Shutterstock/totajla

We recognize that it is important to focus on the positive.

Environmental science often seems to focus on the negative, since one of the outcomes of any analysis of an environmental situation is to highlight problems and point out where change is needed. We often overlook the many positive actions of individuals and organizations. Therefore, each chapter has two features that call attention to the positive:

- **Going Green** boxes describe actions that are having a positive environmental impact. Some of these actions are taken by governments, some are by corporations, and some are individual efforts.

Going Green

From Toilet Water to Tap Water

Reuse of wastewater to recover water is becoming an important strategy in water-stressed areas. Options for water sources used for drinking water continue to evolve. All water, to some extent, is recycled. River water often is withdrawn and used by one city, which returns treated wastewater to the river. A town downstream uses this water as a source for drinking water for its citizens. In situations where municipalities are experiencing shortages of water, many have identified treated wastewater as a source of water that can be reused for other purposes.

Many wastewater recycling programs provide water for agriculture, landscape, or industrial use. Using wastewater for irrigation accounts for 10 percent of irrigation water in developing countries. This is known as *nonpotable reuse*. However, many municipalities are now using treated wastewater as a source for drinking water. No federal laws govern reusing treated wastewater for drinking. However, wastewater destined for reuse as potable water typically undergoes two additional steps not usually part of a typical wastewater treatment plant. Microfiltration and reverse osmosis can remove tiny particles (bacteria, viruses, sediment) and dissolved molecules from the wastewater. In most cases, a city's treated wastewater doesn't go directly into the tap but is piped into the ground, or released into lakes or reservoirs that the municipality uses as its source of drinking water. It mixes with the groundwater or surface water and enters a water treatment plant, where it is processed to meet drinking water standards before being funneled to consumers' taps. This process is known as *indirect potable reuse*. Orange County, California, and St. Petersburg, Florida, use treated wastewater to recharge groundwater. Fairfax County, Virginia, releases its treated wastewater into a reservoir used as a source of drinking water. About 20 percent of the water entering the reservoir is wastewater. The country of Singapore uses treated wastewater for industrial needs, and during water shortages it is added to a reservoir that is a water supply for drinking water.

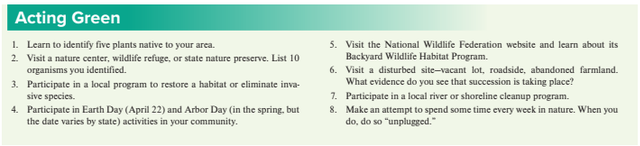
A few cities, in areas with severe water shortages, send treated wastewater directly to a water treatment plant. This is known as *direct potable reuse*. Windhoek, Namibia, is in an extremely water-stressed part of Africa and has been recycling wastewater since 1968. Today, with the construction of a new treatment plant, about 35 percent of its drinking water comes from recycled wastewater. In the United States, Big Spring, Texas, and Wichita Falls, Texas, have both constructed wastewater treatment plants that supply water directly to drinking water treatment plants.

Many Know Merrill/Getty Images

Yet, because of the controversy surrounding this type of water recycling, public acceptance has become as crucial as politics or cost in whether it's implemented. In Toowoomba, Australia, about 100 kilometers (60 miles) west of Brisbane, residents soundly defeated a 2006 proposal to add recycled wastewater to the drinking water supply, despite the area's perpetual water shortage. As periodic drought and population growth create conditions of water shortage and knowledge about wastewater recycling grows, more cities will be looking to wastewater as a source of drinking water. Would you have difficulty drinking "recycled" wastewater? In truth, don't you drink such water already?

Tree icon: stumayhew/Flickr/Getty Images

- **Acting Green** is an end-of-chapter feature that asks students to consider making personal changes that are relatively simple and will have a positive environmental impact.



New to This Edition

The sixteenth edition of *Environmental Science: A Study of Interrelationships* is the result of extensive analysis of the text and the evaluation of input from environmental science instructors who conscientiously reviewed chapters during the revision. We have used the constructive comments provided by these professionals in our continuing efforts to enhance the strengths of the text.

Current Content As with previous editions, the authors have incorporated the most recent information available at the time of publication.

Revised Art Program Over 120 illustrations, graphs, and charts are new or revised to present detailed information in a form that is easier to comprehend than if that same material were presented in text form.

Several Significantly Revised Chapters

Chapter 1 Environmental Interrelationships The chapter has been completely reorganized to provide a better conceptual flow of information. There is greater emphasis on urbanization, globalization, and governance. There is also a new **Issues & Analysis** on federal land-use in the American West and a new **Focus On** dealing with COVID-19.

Chapter 2 Environmental Ethics There is a new **Science, Politics, & Policy** feature on the ethical and political dimensions of climate change.

Chapter 3 Risk, Economics, and Environmental Concerns The **Science, Politics, & Policy:** The Developing Green Economy and the **Issues & Analysis:** The Economics and Risks of Mercury Contamination were significantly revised and updated.

Chapter 5 Interactions: Environments and Organisms There is a new **Focus On** feature dealing with the concept of mass balance, and the **Science, Politics, & Policy** feature on attitudes toward wolves was revised to reflect recent changes in policy.

Chapter 6 Kinds of Ecosystems and Communities A new **Focus On** reading deals with the role of fire in natural ecosystems, and a new **Going Green** feature discusses the North American model of wildlife conservation.

Chapter 7 Populations: Characteristics and Issues The content was updated with the most recent data from the Population Reference Bureau. There is a new **Issues & Analysis:** The Wolves and Moose on Isle Royale with graph of population changes of moose and wolves.

Chapters 8, 9, and 10 all deal with aspects of energy. These chapters have been updated with the most current data available. In **chapter 9 Nonrenewable Energy Sources**, There is a new **Going Green:** Closure of Coal-Fired Power Plants. **Issues & Analysis:** Subsidies for the Energy Sector has been updated to 2016, and material has been reorganized into a table to make it easier to follow. **chapter 10 Renewable Energy Sources**, has a new introduction that compares EROI and Net Energy. There is new material on the nature of solar cells, geothermal heat pump systems, and a tidal current system with accompanying illustrations.

Chapter 11 Biodiversity Issues This chapter has been completely rewritten and reorganized with 25 new illustrations. The new organization focuses on the various levels of biodiversity, the value of biodiversity, threats to biodiversity, and efforts to combat the loss of biodiversity.

Chapter 12 Land-Use Planning There is a new **Science, Politics, & Policy:** Community Planning and Zoning and Conflicts of Interest.

Chapter 14 Agricultural Methods and Pest Management There is a new **Focus On:** Honeybees.

Chapter 15 Water Management There is a new **Focus On:** Cities Where the Water Taps Could Soon Run Dry.

Chapter 16 Air Quality Issues The introductory material on Metropolitan Areas, Traffic, and Air Pollution was significantly rewritten with subheads added to make things easier to understand.

The section on photochemical smog was rewritten and illustrations were revised to include more recent changes in the chemical mechanisms involved in the development of smog.

Science, Politics, & Policy: A History of Mercury Regulations was modified to highlight the different approaches of Bush, Obama, and Trump administrations. In addition, several subheads were added to make it easier to follow the flow. A graph showing the reduction in mercury emissions from power plants was added.

Chapter 17 Climate Change: A Twenty-First Century Issue The chapter has been updated with material on the Madrid climate meeting and a new section on the effect of climate change on oceans was added. There is a new **Going Green:** How Countries Respond to Climate Change.

Chapter 18 Solid Waste Management and Disposal The chapter includes a new section on the impact of China's decision to stop purchase of recycled materials and the impact this has on the recycling industry. There is a new **Issues and Analysis:** Plastics in our Environment.

Chapter 19 Environmental Regulations: Hazardous Substances and Wastes The chapter has been updated throughout. There is a new **Issues & Analysis:** PFAS: A Class of Persistent Organic Pollutants. The **Focus On:** The Hanford Facility: A Storehouse of Nuclear Remains has a new table showing the magnitude of the original problem and the current degree of cleanup.

Chapter 20 Environmental Policy and Decision Making The chapter has been completely rewritten. It begins with a discussion of major global environmental issues needing policy initiatives. This is followed by a discussion of the process of establishing environmental policy with the United States political system as a model and the significance of major U.S. environmental legislation. This is followed by a discussion of the role of the United Nations in fostering international environmental agreements and the difficulties involved in reaching consensus.

There is a new chapter introduction that describes changes in attitudes to environmental policy. There are also new **Science, Politics, & Policy:** The Endangered Species Act–Two Perspectives; a new **Going Green:** Principles for Responsible Investment; and a new **Issues & Analysis:** The Future Has Yet To Be Written.

Acknowledgments

The creation of a textbook requires a dedicated team of professionals who provide guidance, criticism, and encouragement. It is also important to have open communication and dialogue to deal with the many issues that arise during the development and production of a text. Therefore, we would like to thank Portfolio Manager and Product Developer Jodi Rhomberg, Project Manager Jessica Portz, Buyer Sandy Ludovissy, Content Licensing Specialist Beth Cray and Designer David Hash for their suggestions and kindnesses. We would like to thank the following individuals who wrote and/or reviewed learning goal-oriented content for LearnSmart.

Sylvester Allred, *Northern Arizona University*
Ray Beiersdorfer, *Youngstown State University*
Anne H. Bower, *Philadelphia University*
Michelle Cawthorn, *Georgia Southern University*
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Finally, we'd like to thank our many colleagues who have reviewed all, or part, of *Environmental Science: A Study of Interrelationships.* Their valuable input has continued to shape this text and help it meet the needs of instructors around the world.

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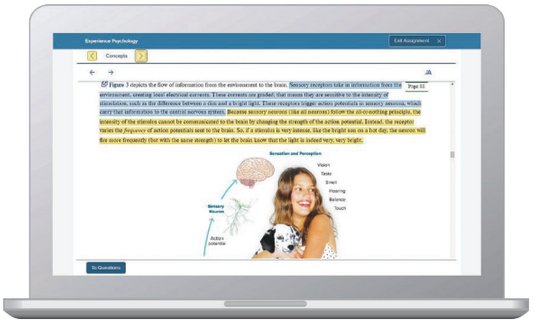

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chapter

1 Environmental Interrelationships

Environmental science is the study of interrelationships between humans and the natural world. This farmer in Uganda has cleared a portion of the original forest to create this small farm, which supplies food and income for the family.
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CHAPTER OUTLINE

OBJECTIVES

After reading this chapter, you should be able to:

- Recognize that the field of environmental science includes social, political, and economic aspects in addition to science.
- Describe examples that illustrate the interrelated nature of environmental science.
- Understand why most social and political decisions are made with respect to political jurisdictions, but environmental problems do not necessarily coincide with these human-made boundaries.
- Understand the concept of sustainability.
- Recognize that human population growth contributes to environmental problems.
- Recognize that people rely on the services provided by ecosystems.
- Understand that food security is an issue for many people in the less-developed world.
- Recognize that there are governance issues that make it difficult to solve environmental problems.
- Recognize that the quality of the environment has an important impact on human health.
- Understand that personal security incorporates economic, political, cultural, social, and environmental aspects.
- Describe environmental impacts of globalization.
- Recognize the central role energy use has on environmental problems.
- Understand that land, soil, and water are resources that need to be managed.
- Recognize that human activities produce waste product that need to be managed.
- State examples of both positive and negative effects of globalization.
- Recognize that the human population is becoming increasingly urbanized.
- List three reasons it is difficult to develop laws and regulations governing environmental issues.

The Important Role of Wolves in Yellowstone

Early explorers of the lands west of the Mississippi River told of a place with fantastic geysers, mud pots, and other thermal features. They also told of abundant wildlife and rivers filled with fish. After several official government expeditions confirmed these tales, Yellowstone National Park was established as the world's first national park in 1872. As more people settled in the west and ranches and farms were established, there was pressure from farmers and ranchers as well as hunters to reduce the number of predator species on public lands in the west. It was also a generally held idea that predators reduced the numbers of elk, deer, and other species preferred by hunters. Thus the U.S. Congress in 1914 provided funding to eliminate wolves and other predators on public lands, including national parks. By 1926 wolves had been eliminated from Yellowstone. The lack of wolves led to a cascade of unintended consequences:

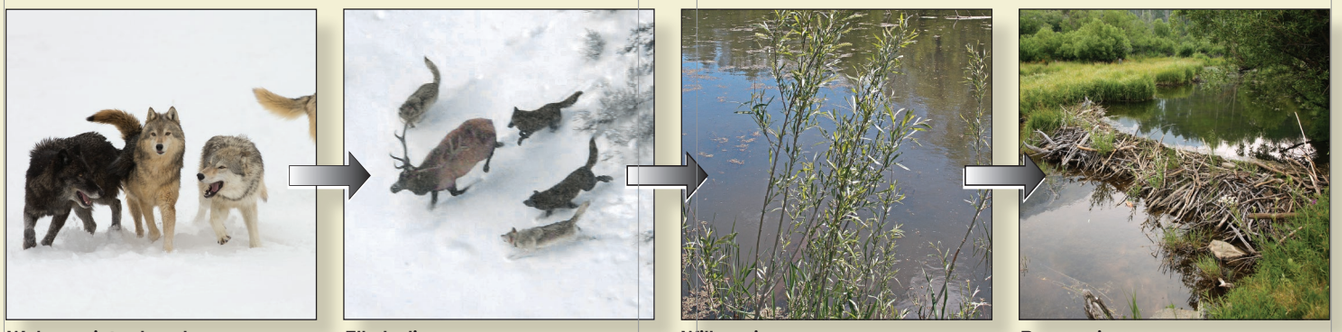
- Since hunting of species other than predators was prohibited in the park, the population of elk increased. In addition, coyotes, which are normally killed by wolves, increased greatly. By 1935, park managers felt that overgrazing by the large population of elk was beginning to destroy the park's habitat. Therefore, a program of harvesting elk, bison, and pronghorns was instituted to protect the habitat. This program was discontinued in the 1960s as better knowledge of the habitat indicated that it was not overgrazed.
- Coyotes greatly reduced the number of small mammal species such as mice, squirrels, and rabbits.
- The number of pronghorn antelope also decreased because coyotes killed newborn pronghorns.
- Populations of cottonwood and willows along streams declined substantially due to browsing by elk.

Eventually, as park managers and biologists began to understand the profound changes caused by the elimination of wolves, the decision was made to reintroduce wolves to Yellowstone National Park. The initial introduction of 31 wolves in 1995 and 1996 has resulted in a current population of about 80 wolves in the park. Several changes to the Yellowstone ecosystem can be directly attributed to the alterations brought about by the return of wolves:

- Wolves kill and eat elk. This has contributed to a significant reduction in the size of the elk herd from about 19,000 prior to wolf reintroduction to about 5,000 now.
- The presence of wolves also has modified the behavior of elk. Because they must be more vigilant and move about more because of the predatory behavior of wolves, elk are organized into smaller herds and spend less time feeding on willow, cottonwood, and aspen. Both the change in behavior and the reduced size of the elk herd have allowed the regeneration of stands of cottonwood and willow along rivers. This has in turn resulted in increased numbers of beavers that use these streamside trees for food and as building materials for their dams. In 1995, there was one beaver colony in Yellowstone. In 2019, there were nine. The dams built by beavers tend to slow the flow of water and increase the recharge of groundwater. Furthermore, the stands of willow along the banks of streams cool the water and improve fish habitat. The stands of willow also provide needed habitat for some songbirds.
- Wolves directly compete with coyotes and kill them if they have the opportunity. Thus, since the reintroduction of wolves the coyote population has fallen significantly. There is evidence that the populations of the prey of coyotes—voles, mice, and other rodents—have increased. The increased availability of this food source has resulted in an increase in the number of foxes, hawks, and owls.
- Predation by wolves has affected the lives of many other kinds of animals. The carcasses of animals killed by wolves are a food source for scavengers such as ravens, eagles, bears, wolverines, and magpies. So, the presence of wolves has had a positive effect. Conversely, wolves usurp the kills of cougars, and cougars have migrated to areas without wolves.

Thus, it is fair to say that the reintroduction of the wolf has changed how water flows through the landscape and has led to increased populations of many organisms—willow, cottonwood, beaver, songbirds, foxes, certain rodents, hawks, and owls; and to the decline in the population of other organisms—coyote and elk. Truly this is a story that illustrates the point made by the early naturalist John Muir (1838–1914)—*When we try to pick out anything by itself, we find it hitched to everything else in the Universe.*

Source: John Muir, ***My First Summer in the Sierra,*** Boston and New York: Houghton Mifflin and Company, 1911.



Wolves reintroduced **Elk decline** **Willows increase** **Beavers increase**

(a): Dennis W Donohue/Shutterstock.com; (b): Source: U.S. National Park Services (NPS); (c): Judy Enger; (d): Yenwen Lu/E+/Getty Images

1.1 The Nature of Environmental Science

Environmental science is an interdisciplinary field that includes both scientific and social aspects of human impact on the world. The word *environment* is usually understood to mean the surrounding conditions that affect organisms. In a broader definition, **environment** is everything that affects an organism during its lifetime. In turn, all organisms including people affect many components in their environment. **Science** is an approach to studying the natural world that involves formulating hypotheses and then testing them to see if the hypotheses are supported or refuted. However, because humans are organized into complex societies, environmental science also must deal with politics, social organization, economics, ethics, and philosophy. Thus, environmental science is a mixture of traditional science, individual and societal values, economic factors, and political realities that are important to solving environmental problems. (See figure 1.1.)

Although environmental science as a field of study is evolving, it is rooted in the early history of civilization. Many ancient cultures expressed a reverence for the plants, animals, and geographic features that provided them with food, water, and transportation. These features are still appreciated by many modern people. Although the following quote from Henry David Thoreau (1817–62) is over a century old, it is consistent with current environmental philosophy:

I wish to speak a word for Nature, for absolute freedom and wildness, as contrasted with a freedom and culture merely civil . . . to regard man as an inhabitant, or a part and parcel of Nature, rather than a member of society.

The current interest in the state of the environment began with philosophers like Thoreau and scientists like Rachel Carson and received emphasis from the organization of the first Earth Day on April 22, 1970. Subsequent Earth Days reaffirmed this commitment. As a result of this continuing interest in the state of the world and how people both affect it and are affected by it, environmental science is now a standard course or program at many colleges. It is also included in the curriculum of high schools. Most of the concepts covered by environmental science courses had previously been taught in ecology, conservation, biology, or geography courses. Environmental science incorporates the scientific aspects of these courses with input from the social sciences, such as economics, sociology, and political science, creating a new interdisciplinary field.

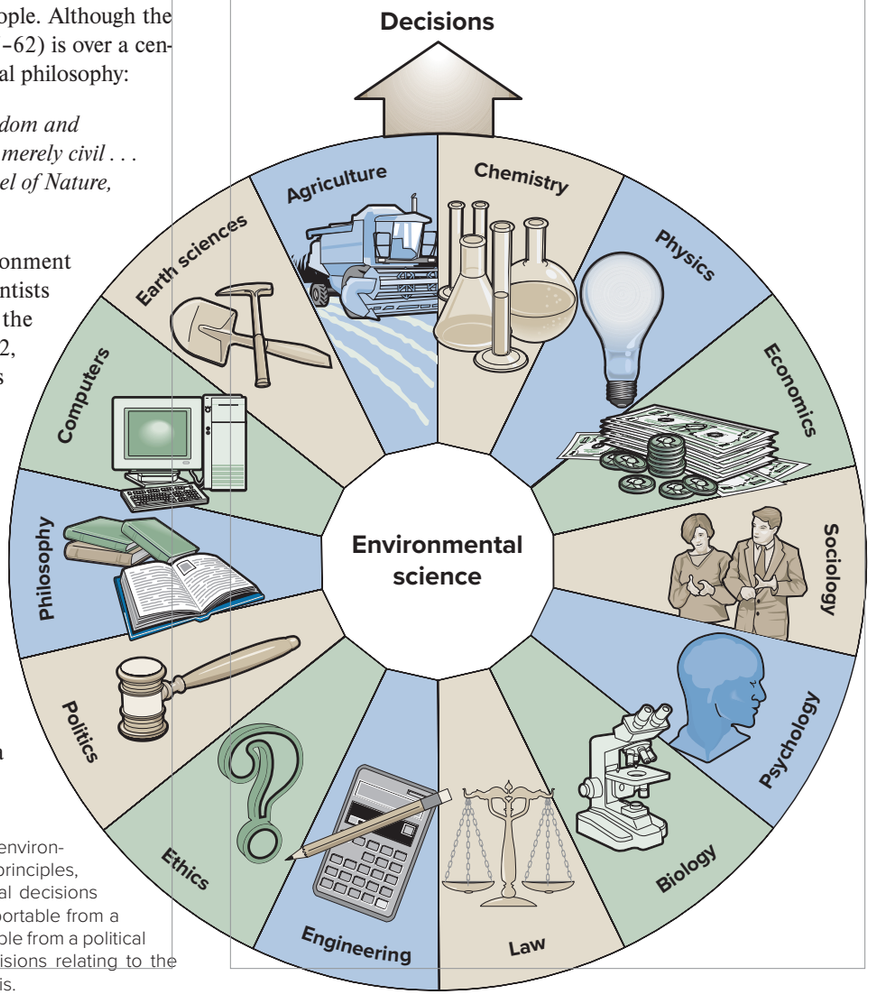


FIGURE 1.1 Environmental Science The field of environmental science involves an understanding of scientific principles, economic influences, and political action. Environmental decisions often involve compromise. A decision that may be supportable from a scientific or economic point of view may not be supportable from a political point of view without modification. Often political decisions relating to the environment may not be supported by economic analysis.

Interrelatedness Is a Core Concept

A central factor that makes the study of environmental science so interesting/frustrating/challenging is the high degree of interrelatedness among seemingly unrelated factors. The opening story about the relationship between wolves and elk in Yellowstone National Park illustrates the theme of interrelatedness very well. The absence of wolves led to an increase in elk and coyotes but to a decrease in beaver, streamside stands of willow and cottonwood, and habitat for some birds. The return of wolves resulted in a decrease in elk numbers and changes in elk behavior that allowed the vegetation to rebound and for beaver to increase in numbers. However, this interrelatedness theme does not just relate to the animal and plant actors in this drama. There is an important human-dominated drama as well that involves philosophical, economic, and political actors.

For example, although many biologists and environmentalists argued that it was important to restore the wolf to its former habitat for biological reasons, others looked at the issue in terms of ethics. They felt that humans had an ethical obligation to restore wolves to their former habitat. While park managers could easily see the problems created by a lack of wolves and a huge elk population, they could not simply make the decision to bring back the wolf. A long