Daniel B. Botkin | Edward A. Keller

ENVIRONMENTAL SCIENCE

EARTH AS A LIVING PLANET

Ninth Edition

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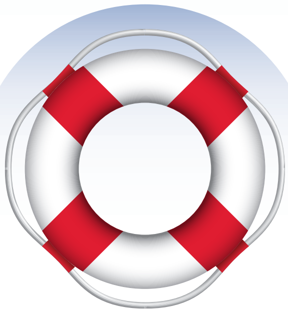

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NINTH EDITION

Environmental Science

Earth as a Living Planet

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This book is printed on acid-free paper.

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Library of Congress Cataloging-in-Publication Data:

ISBN-13: 978-1-118-42732-3
BRV ISBN: 978-1-118-29197-9

Printed in the United States of America

10 9 8 7 6 5 4 3 2 1

Preface

What Is Environmental Science?

Environmental science is a group of sciences that attempt to explain how life on the Earth is sustained, the causes of environmental problems, and how these problems can be solved.

Why Is This Study Important?

- We depend on our environment. We enjoy it and the condition of our environment has a large effect on the quality of our lives. People can only live in an environment with certain kinds of characteristics and within certain ranges of availability of resources. Because modern science and technology give us the power to affect the environment, we have to understand how the environment works, so that we can live within its constraints.
- People have always been fascinated with nature, which, in its broadest view, is our environment. As long as people have written, they have asked three questions about ourselves and nature:

  What is nature like when it is undisturbed by people?

  What are the effects of people on nature?

  What are the effects of nature on people?

Environmental science is our modern way of seeking answers to these questions.

What Is the "Science" in Environmental Science?

Many sciences are important to environmental science. These include biology (especially ecology, the part of biology that deals with the relationships among living things and their environment), geology, hydrology, climatology, meteorology, oceanography, and soil science.

How Is Environmental Science Different from other Sciences?

It involves many sciences.
It includes sciences, but also involves related nonscientific fields that have to do with how we value the environment, from environmental philosophy to environmental economics.
It deals with many topics that have great emotional effect on people, and therefore are subject to political debate and to strong feelings that often ignore scientific information.

What Is Your Role as a Student and as a Citizen?

Your role is to understand how to think through environmental issues so that you can arrive at your own conclusions.

What Are the Professions That Grow Out of Environmental Science?

Many professions have grown out of the modern concern with environment, or have been extended and augmented by modern environmental sciences. These include park, wildlife, and wilderness management; urban planning and design; landscape planning and design; conservation and sustainable use of our natural resources; pollution control; environmental energy engineering.

Goals of This Book

Environmental Science: Earth as a Living Planet provides an up-to-date introduction to the study of the environment. Information is presented in an interdisciplinary perspective necessary to deal successfully with environmental problems. The goal is to teach you, the student, how to think through environmental issues.

Critical Thinking

We must do more than simply identify and discuss environmental problems and solutions. To be effective, we must know what science is and is not. Then, we need to develop critical thinking skills. Critical thinking is so important that we have made it the focus of its own chapter, Chapter 2. With this need in mind, we have also developed *Environmental Science* to present the material in a factual and unbiased format. Our goal is to help you think through the issues, not tell you what to think. To this purpose, at the end of each chapter, we present "Critical Thinking Issues." Critical thinking is further emphasized throughout the text in analytical discussions of topics, evaluation of perspectives, and integration of important themes, which are described in detail later.

Interdisciplinary Approach

The approach of *Environmental Science* is interdisciplinary in nature. Environmental science integrates many disciplines, including the natural sciences, in addition to fields such as anthropology, economics, history, sociology, and philosophy of the environment. Not only do we need the best ideas and information to deal successfully with our environmental problems, but we also must be aware of the cultural and historical contexts in which we make decisions about the environment. Thus, the field of environmental science also integrates the natural sciences with environmental law, environmental impact, and environmental planning.

Themes

Our book is based on the philosophy that six threads of inquiry are of particular importance to environmental science. These key themes—human population, sustainability, global perspective, urban world, people and nature, and science and values—are woven throughout the book.

These six key themes are discussed in more detail in Chapter 1. They are also revisited at the end of each chapter and are emphasized in the Closer Look boxes, each of which is highlighted by an icon suggesting the major underlying theme of the discussion. In many cases, more than one theme is relevant.

Human Population

Underlying nearly all environmental problems is the rapidly increasing human population. Ultimately, we cannot expect to solve environmental problems unless the total number of people on Earth is an amount the environment can sustain. There is considerable debate about what are practical limits to what can be sustained.

Sustainability

Sustainability means that a resource is used in a way that it continues to be available. However, the term is used vaguely, and it is a concept experts continually struggle to clarify. Some would define it as ensuring that future generations have equal opportunities to access the resources that our planet offers. Others would argue that sustainability refers to types of developments that are economically viable, do not harm the environment, and are socially just. We all agree that we must learn how to sustain our environmental resources so that they continue to provide benefits for people and other living things on our planet.

A Global Perspective

Until recently, it was common to believe that human activity caused only local, or at most regional, environmental change. We now know that human activities can affect the environment globally. An emerging science known as Earth System Science seeks a basic understanding of how our planet's environment works as a global system. This understanding can then be applied to help solve global environmental problems. The emergence of Earth System Science has opened up a new area of inquiry for faculty and students.

The Urban World

An ever-growing number of people are living in urban areas. Unfortunately, our urban centers have long been neglected, and the quality of the urban environment has suffered. It is here that we experience the worst of air pollution, waste-disposal problems, and other stresses on the environment. In the past our studies of the environment have focused more on wilderness than on the urban environment. In the future we must place greater emphasis on towns and cities as livable environments.

People and Nature

People seem to be always interested—amazed, fascinated, pleased, curious—in our environment. Why is it suitable for us? How can we keep it that way? We know that people and our civilizations are having major effects on the environment, from local effects (the street where you live) to the entire planet (we have created a hole in the Earth's ozone layer), which can affect us and many forms of life.

Science and Values

Finding solutions to environmental problems involves more than simply gathering facts and understanding the scientific issues of a particular problem. It also has much to do with our systems of values and issues of social justice. To solve our environmental problems, we must understand what our values are and which potential solutions are socially just. Then we can apply scientific knowledge about specific problems and find acceptable solutions.

Special Features

In writing *Environmental Science* we have designed a text that incorporates a number of special features that we believe will help teachers to teach and students to learn. These include the following:

A **Case Study** introduces each chapter. The purpose of this feature is to interest students in the chapter's subject and to raise important questions on the subject matter For example, in Chapter 11, Agriculture, Aquaculture, and Environment, the opening case study tells about a farmer feeding his pigs trail mix, banana chips, yogurt-covered raisins, dried papaya, and cashews because growing corn for biofuels is raising the costs of animal feed so much.

Learning Objectives at the beginning of each chapter challenge students to apply the knowledge in the chapter to solve some problems and to integrate the chapter's materials.

A **Closer Look** is the name of special learning modules that present more detailed information concerning a particular concept or issue. For example, A Closer Look 13.2 discusses the reasons for conserving endangered species.

Many of these special features contain **figures** and **data** designed to enrich the reader's understanding and relate back to the book themes.

Near the end of each chapter, a **Critical Thinking Issue** encourages critical thinking about the environment, helping students understand how the issue may be studied and evaluated. For example, Chapter 22 presents a critical thinking issue title "How Can Urban Sprawl Be Controlled?"

Following the Summary, a special section, **Reexamining Themes and Issues**, reinforces the six major themes of the textbook.

Study Questions for each chapter provide a study aid, emphasizing critical thinking.

Further Readings are provided with each chapter so that students may expand their knowledge by reading additional sources of information (both print and electronic) on the environment.

References cited in the text are provided at the end of each chapter as notes for each chapter. These are numbered according to their citation in the text. We believe it's important that introductory textbooks carefully cite sources of information used in the writing. These sources are provided to help students recognize those scholars whose work we depend on, and to encourage students to draw upon these references as needed for additional reading and research.

Changes in the Ninth Edition

Environmental science is a rapidly developing set of fields and our scientific understanding of the environment is also changing rapidly. Even the kinds of connections between science and our ways of life change. In addition, the environment itself is changing rapidly: Populations grow; species become threatened or released from near extinction; our actions change. To remain contemporary, a textbook in environmental science requires frequent updating, and with this edition we have examined the entire text and worked to streamline and update every chapter.

Other changes in the ninth edition include the following:

- Several chapters have been deleted and their material integrated into other chapters, to shorten the book and make it more readable.
- Biological Production and Ecosystem Energy Flow material now integrated into new Ecosystems and Ecological Restoration chapters.
- Economics and Environment Chapter has been moved to the third chapter, because this is so basic to the entire discussion of environmental sicence applications.
- Revision of the basic energy and fossil fuel chapters to reflect the tremendous changes that have occurred as a result of exploiting the oil and natural gas resources that have become available in the United States.
- An updated Global Change that presents a balanced coverage of this important Environmental Science topic.
- New Case Studies have been added, including "Conservation Concessions: How to Save 200,000 Acres of Tropical Rainforest," "Pacific Salmon: Iconic Fish of the Pacific Northwest," and "Air Pollution in China 2013."
- An in-depth discussion about the processes of learning and discovery in Environmental Science, with steps to creative thinking and higher cognitive abilities.
- New and updated Closer Look Boxes, and Critical Thinking Issues.
- Learning Objectives for each chapter have been completely revised to provide the student with challenging activities.

Updated features help engage students in the key issues and topics of environmental science, and provide resources for instructors to foster dynamic in-class discussion

Augmentation of WebSite References

Valid information is becoming increasingly available via the Web, and easy access to this data is of great value. Government data that used to take weeks of library research to find are available almost instantly on the Internet Web site. For this reason, we have greatly augmented the number of website references and have gathered them all on the book's companion site.

Updated Case Studies

Each chapter begins with a case study that helps the student learn about the chapter's topic through a specific example. A major improvement in the ninth edition is the replacement of some older case studies with new ones that discuss current issues and are more closely integrated into the chapter.

Updated Critical Thinking Issues

Each chapter ends with a discussion of an environmental issue, with critical thinking questions for the students. This is one of the ways that the text is designed to help students learn to think for themselves about the analysis of environmental issues. Answers to the end of chapter questions are available for instructor use with the Instructors Manual.

Support

Environmental Science, Ninth Edition, features a full line of teaching and learning resources developed to help professors create a more dynamic and innovative learning environment. For students, we offer tools to build their ability to think clearly and critically.

For Students **WileyPLUS**

Different learning styles, different levels of proficiency, different levels of preparation - each student is unique. WileyPLUS empowers them to take advantage of their individual strengths. With WileyPLUS, students receive timely access to resources that address their demonstrated needs, and get immediate feedback and remediation when needed.

Integrated multimedia resources include:

- **Environmental Science Basics** provides a suite of animated concepts and tutorials to give students a solid grounding in key basic environmental concepts. Concepts ranging from global climate change to sustainable agriculture are presented across 21 modules in easy-to-understand language.
- **Environmental Science Videos** cover the current key stories relating to environmental science; they include clips from the BBC and CBS news.
- **Virtual Field Trip Videos** allow students to go to different places around the world and gain a better understanding of

the environment and our impact on it. Through these video-based field trips, students gain virtual on-the-ground experience using their WileyPLUS course

- **Animations.** Select text concepts are illustrated using flash animations for student self-study or classroom presentation.
- **Virtual Discovery Labs.** These select Virtual Labs bring core laboratory concepts to life in an online lab setting.

For Instructors

Instructor's Manual

The Instructor's Manual (IM), prepared by James Yount of Brevard Community College, highlights and discusses key concepts, definitions, equations, and examples from each chapter. It also provides answers to the in-text critical thinking and end-of-chapter study questions.

Test Bank

The Test Bank, updated and revised by Anthony Gaudin of Ivy Tech Community College, includes approximately 2,000 questions, in multiple-choice, short-answer, and essay formats. The Test Bank is provided in a word.doc format for your convenience to use and edit for your individual needs. For this edition, the author has created many new questions and has labeled the boxed applications according to the six themes and issues set forth in the text. In addition, the author has created questions for the theme boxes and emphasized the themes in many of the questions throughout the test bank.

Respondus Test Bank

The Respondus Test Bank provides tests and quizzes for *Environmental Science* Ninth Edition for easy publication into your LMS course, as well as for printed tests. The Respondus Test Bank includes all of the files from the Test Bank, Practice Quizzes, and Pre and Post Lecture Questions in a dynamic computerized format. *For schools without a campus-wide license to Respondus, Wiley will provide one for no additional cost.

Video Lecture Launchers

A rich collection of videos have been selected to accompany key topics in the text. Accompanying each of the videos are contextualized commentary and questions in PowerPoint format that facilitate easy in-class use.

PowerPoint™ Presentations

Prepared by Donald Williams of Park University, these presentations are tailored to the text's topical coverage and are designed to convey key concepts, illustrated by embedded text art.

Advanced Placement® Guide for Environmental Science

Prepared by Brian Kaestner of Saint Mary's Hall, this resource is available on the Instructor's Resource Web site (www.wiley.com/college/botkin). The Advanced Placement Guide provides a useful tool for high school instructors who are teaching the AP® Environmental Science course. This guide will help teachers to focus on the key concepts of every chapter to prepare students for the Advanced Placement® Exam. Each chapter includes a Chapter Overview that incorporates critical thinking questions, Key Topics important to the exam, and Web links to Laboratories and Activities that reinforce key topics.

Book Companion Site

All instructor resources (the Test Bank, Instructor's Manual, PowerPoint presentations, and all textbook illustrations and photos in jpg format) are housed on the book companion site (www.wiley.com/college/botkin). Student resources include self quizzes and flashcards.

Also Available

Environmental Science: Active Learning Laboratories and Applied Problem Sets, 2e by Travis Wagner and Robert Sanford both of University of Southern Maine, is designed to introduce students to the broad, interdisciplinary field of environmental science by presenting specific labs that use natural and social science concepts to varying degrees, and encourages a "hands on" approach to understanding the impacts from the environmental/human interface. The laboratory and homework activities are designed to be low-cost and to reflect a sustainability approach in practice and in theory. *Environmental Science: Active Learning Laboratories and Applied Problem Sets, 2e* is available stand-alone or in a package with *Environmental Science, 9e*. Contact your Wiley representative for more information.

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Acknowledgments

Completion of this book was possible only through the cooperation and work of many people. To all those who so freely offered their advice and encouragement in this endeavor, we offer our most sincere appreciation. We are indebted to our colleagues who made contributions.

We greatly appreciate the work of our editors at John Wiley & Sons, Rachel Falk and Ryan Flahive, for support, encouragement, assistance, and professional work. We extend thanks to our production editor Trish McFadden, who did a great job and made important contributions in many areas; to Wendy Lai for a beautiful interior design; and to Billy Ray for photo research. Thanks go out also for editorial assistance from Elizabeth Baird and Chloe Moffett.

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Photo by Maguire Neblet

Daniel B. Botkin is Professor (Adjunct), Department of Biology, University of Miami, Coral Gables, Florida, and Professor Emeritus of Ecology, Evolution, and Marine Biology, University of California, Santa Barbara, where he joined the faculty in 1978, serving as chairman of the Environmental Studies Program from 1978 to 1985. For more than four decades, Professor Botkin has been active in the application of ecological science to environmental management. He is winner of Santa Barbara Botanic Garden's John C. Pritzlaff Conservation Award in 2012, in recognition of his career contributions to conservation of biodiversity. Other awards include Oxford University Astor Lectureship, 2007; the Mitchell International Prize for Sustainable Development, and the Fernow Prize for International Forestry; he has also been elected to the California Environmental Hall of Fame.

Trained in physics and biology, Professor Botkin is a leader in the application of advanced technology to the study of the environment. The originator of widely used forest gap-models, he has conducted research on endangered species, characteristics of natural wilderness areas, the biosphere, and global environmental problems, including possible ecological effects of global warming. During his career, Professor Botkin has advised the World Bank about tropical forests, biological diversity and sustainability; the Rockefeller Foundation about global environmental issues; the government of Taiwan about approaches to solving environmental problems; and the state of California on the environmental effects of water diversion on Mono Lake. He served as the primary advisor to the National Geographic Society for its centennial edition map on "The Endangered Earth." He directed a study for the states of Oregon and California concerning salmon and their forested habitats.

He has published many articles and books about environmental issues. His latest books are: *The Moon in the Nautilus Shell: Discordant Harmonies Reconsidered (Oxford University Press, 2012*) and *Powering the Future: A Scientist's Guide to Energy Independence (FT Press, 2010)*. His other books are: *Beyond the Stoney Mountains: Nature in the American West from Lewis and Clark to Today* (Oxford University Press) and available as an ebook (Croton River Publishers); *Strange Encounters: Adventures of a Renegade Naturalist* (Penguin/Tarcher), *The Blue Planet* (Wiley), available as an ebook (Croton River Publishers); *No Man's Garden: Thoreau and a New Vision for Civilization and Nature* (Island Press; now available as an ebook (Croton River Publishers); *Passage of Discovery: The American Rivers Guide to The Missouri River of Lewis and Clark* (Perigee Books (a Division of Penguin-Putnam, now available as an ebook (Croton River Publisher); *Our Natural History: The Lessons of Lewis and Clark* (Oxford University Press), *Discordant Harmonies: A New Ecology for the 21st Century* (Oxford University Press), and *Forest Dynamics: An Ecological Model* (Oxford University Press).

Professor Botkin was on the faculty of the Yale School of Forestry and Environmental Studies (1968–1974) and was a member of the staff of the Ecosystems Center at the Marine Biological Laboratory, Woods Hole, MA (1975–1977). He received a B.A. from the University of Rochester, an M.A. from the University of Wisconsin, and a Ph.D. from Rutgers University.

Edward A. Keller was chair of the Environmental Studies and Hydrologic Sciences Programs from 1993 to 1997 and is Professor of Earth Science at the University of California, Santa Barbara, where he teaches earth surface processes, environmental geology, environmental science, river processes, and engineering geology. Prior to joining the faculty at Santa Barbara, he taught geomorphology, environmental studies, and earth science at the University of North Carolina, Charlotte. He was the 1982–1983 Hartley Visiting Professor at the University of Southampton, a Visiting Fellow in 2000 at Emmanuel College of Cambridge University, England, and recipient of the Easterbrook Distinguished Scientist award from the Geological Society of America in 2004.

Professor Keller has focused his research efforts into three areas: studies of Quaternary stratigraphy and tectonics as they relate to earthquakes, active folding, and mountain building processes; hydrologic process and wildfire in the chaparral environment of Southern California; and physical habitat requirements for the endangered Southern California steelhead trout. He is the recipient of various Water Resources Research Center grants to study fluvial processes and U.S. Geological Survey and Southern California Earthquake Center grants to study earthquake hazards.

Professor Keller has published numerous papers and is the author of the textbooks *Environmental Geology*; *Introduction to Environmental Geology*; *Natural Hazards* (with Duane DeVecchio); and *Active Tectonics* (with Nicholas Pinter). He holds bachelor's degrees in both geology and mathematics from California State University, Fresno, an M.S. in geology from the University of California, and a Ph.D. in geology from Purdue University.

Dedications

For my sister, Dorothy B. Rosenthal

who has been a source of inspiration, support, ideas,
and books to read, and is one of my harshest and best critics.

Dan Botkin

For Valery Rivera

who contributed so much to this book and
is a fountain of inspiration in our work and lives.

Ed Keller

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CHAPTER 1

Key Themes in Environmental Sciences

LEARNING OBJECTIVES

Certain themes are basic to environmental science. After reading this chapter, you should be able to . . .

- Construct an argument to support the idea that people and nature are intimately connected
- Defend or criticize the statement that human environmental health problems are largely caused by social phenomena and human population increase
- Differentiate between the ways we place value on the environment
- Define sustainability and list the major criteria to assist in achieving sustainability
- Critically appraise the statement "think globally and act locally"
- Compare and contrast positive and negative aspects of the urban environment
- Support the idea that value judgments are necessary to adopt a solution to human population based on scientific knowledge
- Argue in support of the Precautionary Principle and then criticize your argument
- Synthesize the environmental implications of the history of Easter Island

Salmon Fishing Alaska.

James Watt/Perspectives/Getty Images

CASE STUDY

Pacific Salmon: Iconic Fish of the Pacific Northwest

Legend has it that 9,000 years ago the Pacific Northwest tribe, the Chinook People (First People) needed some help with a sustainable food supply. Coyote, a mythological character found in the legends of many Indian tribes, came to the rescue. He connected the Columbia River to an upstream pond where women were keeping two fish. Coyote knew more people would come, so he decreed that the fish would swim from the pond to the ocean and return to become food for the people.

The fish returned, and Coyote taught the people how to fish; the people prospered. When Meriwether Lewis and William Clark reached the mouth of the Columbia River in November of 1805 with the Corps of Discovery, they observed the celebration of the first catch of king salmon (chinook salmon) of the season. The fish were eaten fresh and preserved by drying. The Chinook People then pounded the dried fish into a powder that they pressed into loaves that could be used for several years.

Salmon fishing in the United States by people of European descent started after the Civil War. The catch increased rapidly, peaking in the 1920s, and then declined to much lower levels (Figure 1.1). Today, some salmon runs are listed as endangered or threatened under the U.S. Endangered Species Act of 1973, and billions of dollars are being invested to restore runs of salmon.[1]

There are six species of salmon along the Pacific coast of the United States, ranging from California to Alaska. These are called anadromous fish because they spend part of their lives in fresh water and part in the ocean. Eggs are hatched and the young grow in fresh waters; then the fish migrate to the ocean, where they feed and grow, returning to the river of their origin in four to six years to spawn. About 85% of salmon return to a place on the river that is very close to where they first emerged as eggs (Figure 1.2). (The life cycle of salmon is shown in Figure 1.3.)

Salmon affect their freshwater habitats. The young are predators on insects and are themselves the food of birds, river otters, bears, and other predators of fish. Adult salmon that return from the ocean provide an annual food for large animals and birds, from bears to eagles. Also, many forests and their streams in salmon country are phosphorus poor. During the ocean phase of their lives, salmon take up phosphorus in their food. When the salmon die in fresh water after spawning, their phosphorus is added to the river, and, if the fish are taken from the river by bears and eagles, then the phosphorus is spread more widely.

There are six salmon species that return to inland waterways from the Pacific: chinook (king), sockeye, chum, pink, coho (silver), and steelhead. Each has different freshwater habitats and travels different distances from the ocean. Chum salmon spawn just inland, in estuaries or near mouths of stream. In contrast, sockeye, which is common far north, such as in the Frazier River, Alaska, migrate as far as 1,000 km upstream. On their river travels, salmon often endure warm river temperatures, and, as famously seen in so many photographs and movies, often must leap high to travel up rapids and falls and

(*Source:* Washington and Oregon Departments of Fish and Wildlife.)

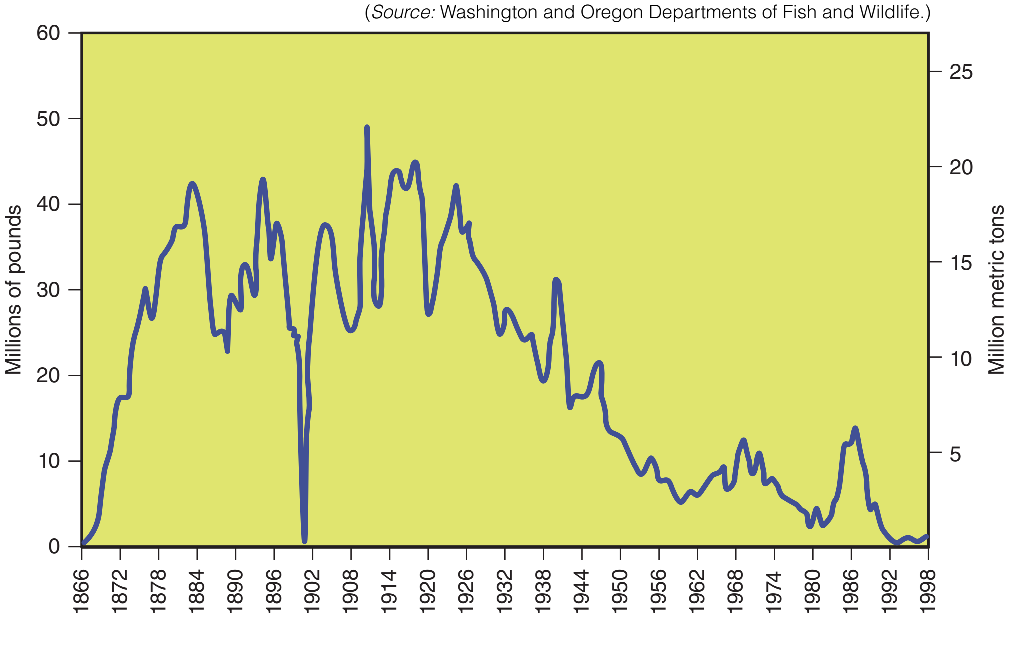


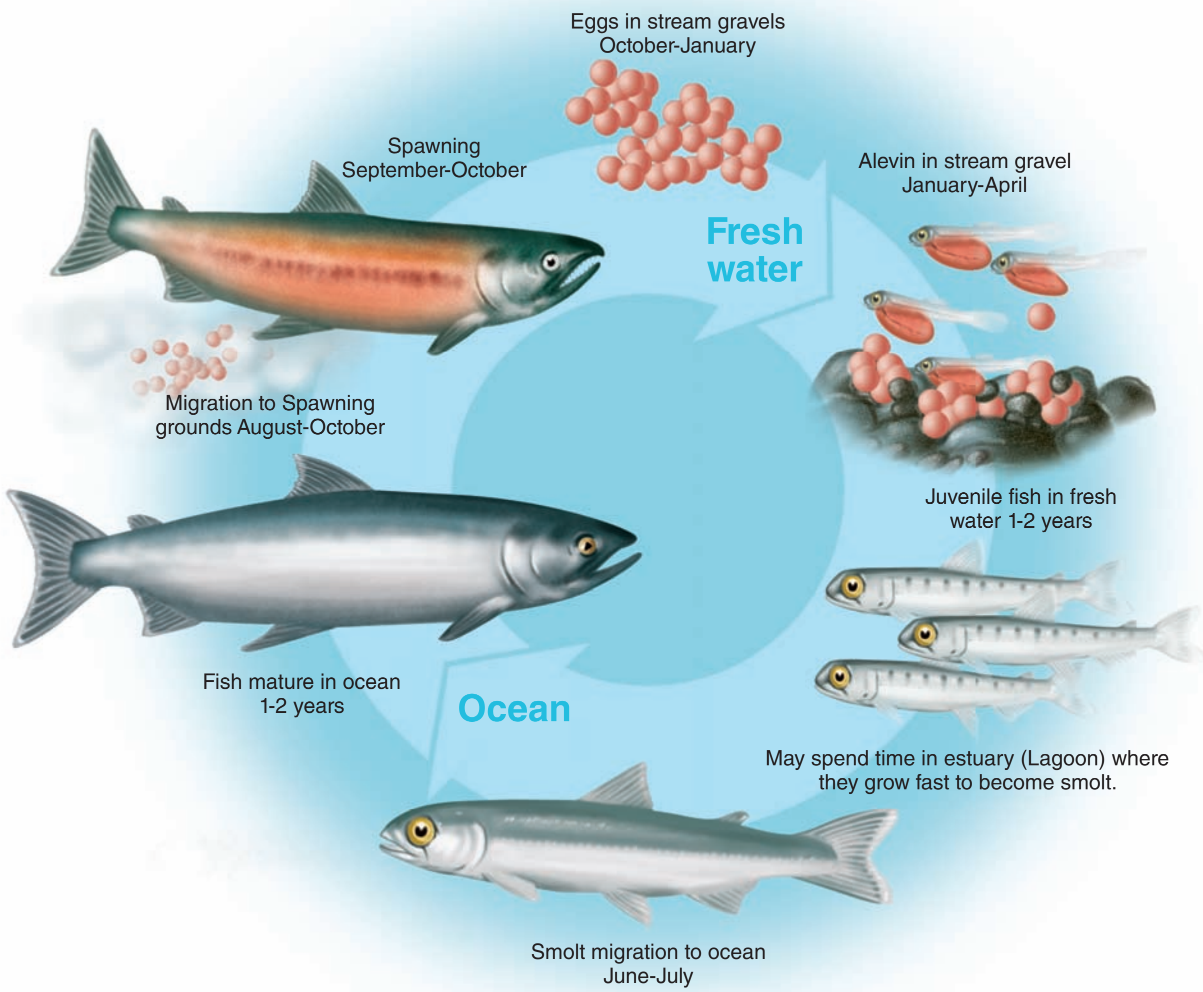
FIGURE 1.1 Commercial salmon catch in the Columbia River, 1866–2000. There is no data for 1901. The catch in 2011 was about 1–2 million tons (0.45–0.90 metric tons).

Steven Kazlowski/NG Image Collection

FIGURE 1.2 Sockeye salmon spawning in an Alaskan River.

swim through very fast-running water. Because salmon tend to return to the same stream where they were born, each stream's population can be genetically isolated from others long enough so that different populations differ genetically from each other. The American Fisheries Society has listed up to 500 genetically distinct salmon populations among the six species. Unfortunately, numerous populations of salmon have declined in many rivers in northern California, Oregon, Washington, British Columbia, and Alaska.

Salmon are important to various ecosystem food chains. They have been long vital to the cultures of Native Americans, as we see in the Coyote legend. Salmon fishing is also a major recreational activity benefiting many towns along the Pacific coast. Moreover, there is a worldwide market for salmon. As a result, many attempts have been made to increase the size of salmon populations. The four culprits usually listed as causes of decline in salmon populations are overfishing by people, forest logging that destroys spawning and the breeding habitat, construction of dams that interfere with salmon migration, and harvests of salmon by sea lions.



(*Source:* Based on figures from Alaskan Department of Fish and Game and the US Fish and Wildlife Service).

FIGURE 1.3 **Life cycle of Pacific salmon.**

But other factors, which receive less attention, may also be important. These include problems arising from hatchery-bred fish intermixing with wild fish, thereby mixing genotypes that may be less well adapted to a stream; pollution of streams and therefore salmon habitat from agricultural chemical runoff; and introduction of exotic species, such as parasites, predators, and competitors with native species and populations.[2] Deforestation also leads to warmer waters and the addition of fine sediment that plugs stream gravel, reducing oxygen and egg vitality.

So what is the future of salmon, these iconic fish of the Pacific Northwest, often viewed as an indicator of the health of our rivers? Large amounts of money have been spent to study the life cycle of salmon in various rivers and to develop management plans. In general, these efforts have varied from unsuccessful to moderately successful.

The history of salmon exploitation around the world, from Europe to the United States, as it is with most fish species, seems to follow a similar pattern: discovery of a very abundant source; habitat degradation; and then overfishing that leads to great declines, sometimes leaving populations so low as to make harvests impractical. The good news is that it is very likely that many salmon populations will recover, although probably not to pre-European settlement levels.[3]

The story of Pacific Northwest salmon emphasizes the six major themes of *Environmental Science:*

1. Human population increase has impacted salmon habitat.
2. We are concerned for the future (sustainability) of salmon.
3. Climate change, with warming river water and changing flows, is impacting the future of salmon.
4. Urbanization of coastal areas impacts some rivers where salmon are present.
5. People and salmon in the Pacific Northwest have shared a common history for thousands of years.
6. While science can provide choices to manage salmon, the choices we make will reflect our values.

1.1 Major Themes of Environmental Science

The study of environmental problems and their solutions has never been more important. Modern society is hooked on oil. Production has declined, while demand has grown, and the population of the world has been increasing by more than 70 million each year. The emerging energy crisis is producing an economic crisis, as the prices of everything produced from oil (fertilizer, food, and fuel) rises beyond what some people can afford to pay. Energy and economic problems come at a time of unprecedented environmental concerns, from the local to global level.

At the beginning of the modern era—in A.D. 1—the number of people in the world was probably about 100 million, one-third of the present population of the United States. In 1960, the world contained 3 billion people. Our population has more than doubled in the last 50 years to about 7 billion people in 2013. In the United States, population increase is often apparent when we travel. Urban traffic snarls, long lines to enter national parks, and difficulty getting tickets to popular attractions are all symptoms of a growing population. If recent human population growth rates continue, our numbers could reach 9.4 billion by 2050.[4] The problem is that the Earth has not grown any larger, and the abundance of its resources has not increased—in many cases, quite the opposite. How, then, can Earth sustain all these people? And what is the maximum number of people that could live on Earth, not just for a short time but *sustained* over a long period?

Estimates of how many people the planet can support range from 2.5 billion to 40 billion (a population not possible with today's technology). Why do the estimates vary so widely? Because the answer depends on what quality of life people are willing to accept. Beyond a threshold world population of about 4–6 billion, the quality of life declines. How many people the Earth can sustain depends on *science and values* and is also a question about *people and nature*. The more people we pack onto the Earth, the less room and resources there are for wild animals and plants, wilderness, areas for recreation, and other aspects of nature—and the faster Earth's resources will be used. The answer also depends on how the people are distributed on the Earth—whether they are concentrated mostly in cities or spread evenly across the land.

Although the environment is complex and environmental issues seem sometimes to cover an unmanageable number of topics, the science of the environment comes down to the central topics just mentioned: the human population, urbanization, and sustainability within a global perspective. These issues have to be evaluated in light of the interrelations between people and nature, and the answers ultimately depend on both science and nature.

This book therefore approaches environmental science through six interrelated themes:

1. *Human population growth* (the environmental problem)
2. *Sustainability* (the environmental goal)
3. *A global perspective* (many environmental problems require a global solution)
4. *An urbanizing world* (most of us live and work in urban areas)
5. *People and nature* (we share a common history with nature)
6. *Science and values* (science provides solutions; which ones we choose are in part value judgments)

You may ask, "If this is all there is to it, what is in the rest of this book?" (See A Closer Look 1.1.) The answer lies with the old saying "The devil is in the details." The solution to specific environmental problems requires specific knowledge. The six themes listed above help us see the big picture and provide a valuable background. The opening case study illustrates linkages among the themes, as well as the importance of details.

In this chapter we introduce the six themes with brief examples, showing the linkages among them and touching on the importance of specific knowledge that will be the concern of the rest of the book. We start with human population growth.

1.2 Human Population Growth

Our Rapid Population Growth

The most dramatic increase in the history of the human population occurred in the last part of the 20th century and continues today into the early 21st century. As mentioned, in merely the past 50 or so years, the human population of the world has more than doubled—to more than 7 billion. Figure 1.4 illustrates this population explosion, sometimes referred to as the "population bomb." The figure shows that the expected decrease in population in the developed regions (for example, the United States and western Europe) is more than offset by rapid population growth in the developing regions (for example, Africa, India, and South America).

A CLOSER LOOK 1.1

A Little Environmental History

A brief historical explanation will help clarify what we seek to accomplish. Before 1960, few people had ever heard the word *ecology,* and the word *environment* meant little as a political or social issue. Then came the publication of Rachel Carson's landmark book, *Silent Spring* (Boston: Houghton Mifflin, 1960, 1962). At about the same time, several major environmental events occurred, such as oil spills along the coasts of Massachusetts and southern California and highly publicized threats of extinction of many species, including whales, elephants, and songbirds. The environment became a popular issue.

As is true of any new social or political issue, at first relatively few people recognized its importance. Those who did found it necessary to stress the problems—to emphasize the negative—in order to bring public attention to environmental concerns. Adding to the limitations of the early approach to environmental issues was a lack of scientific knowledge and practical know-how. Environmental sciences were in their infancy. Some people even saw science as part of the problem.

The early days of modern environmentalism were dominated by confrontations between those labeled environmentalists and those labeled anti-environmentalists. Stated in the simplest terms, environmentalists believed that the world was in peril. To them, economic and social development meant destruction of the environment and ultimately the end of civilization, the extinction of many species, and perhaps the extinction of human beings. Their solution was a new worldview that depended only secondarily on facts, understanding, and science. In contrast, again in simplest terms, the anti-environmentalists believed that whatever the environmental effects, social and economic health and progress were necessary for people and civilization to prosper. From their perspective, environmentalists represented a dangerous and extreme view with a focus on the environment to the detriment of people, a focus they thought would destroy the very basis of civilization and lead to the ruin of our modern way of life.

Today, the situation has changed. Public-opinion polls now show that people around the world rank the environment among the most important social and political issues. There is no longer a need to prove that environmental problems are serious.

We have made significant progress in many areas of environmental science (although our scientific understanding of the environment still lags behind our need to know). We have also begun to create legal frameworks for managing the environment, thus providing a new basis for addressing environmental issues. The time is now ripe to seek truly lasting, more rational solutions to environmental problems.

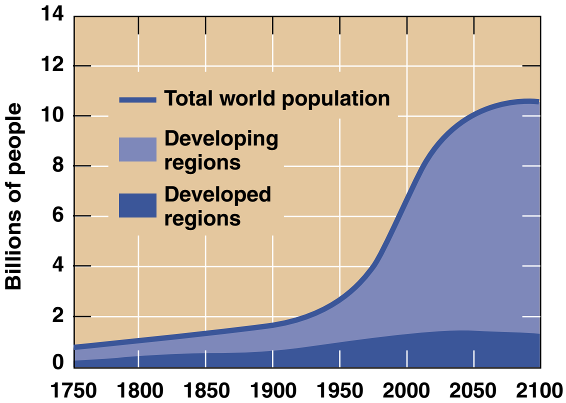


FIGURE 1.4 Population growth in developed and developing nations. 1750 projected to 2100.

Human population growth is, in some important ways, *the* underlying issue of the environment. Much current environmental damage is directly or indirectly the result of the very large number of people on Earth and our rate of increase. As you will see in Chapter 5, where we consider the human population in more detail, for most of human history, the total population was small and the average long-term rate of increase was low relative to today's growth rate.[4]

Although it is customary to think of the population as increasing continuously without declines or fluctuations, the growth of the human population has not been a steady march. For example, great declines occurred during the time of the Black Death in the 14th century. At that time, entire towns were abandoned, food production declined, and in England one-third of the population died within a single decade.[5]

Famine and Food Crisis

Famine is one of the phenomena that happen when a human population exceeds its environmental resources. Famines have occurred in recent decades in Africa. In the mid-1970s, following a drought in the Sahel region, 500,000 Africans starved to death and several million more were permanently affected by malnutrition.[6] Starvation in African nations gained worldwide attention some ten years later, in the 1980s.[7, 8]

Famine in Africa has had multiple interrelated causes. One, as suggested, is drought. Although drought is not new to Africa, the size of the population affected by drought is unprecedented. In addition, deserts in Africa appear to be spreading, in part because of changing climate but also because of human activities. Poor farming practices have increased erosion, and deforestation may be helping to make the environment drier. In addition, the control and destruction of food have sometimes been used as a weapon in political disruptions (Figure 1.5). Today, malnutrition contributes to the death of about 6 million children per year. Low- and middle-income countries suffer the most from malnutrition, as measured by low weight for age (underweight, as shown in Figure 1.6).[9]

The emerging global food crisis in the first decade of the 21st century has not been caused by war or drought but by rising food costs. The cost of basic items, such as rice, corn, and wheat, has risen to the point where

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FIGURE 1.5 Science and values. Social conditions affect the environment, and the environment affects social conditions. Political disruption in Somalia (illustrated by a Somalian boy with a gun, left photo) interrupted farming and food distribution, leading to starvation. Overpopulation, climate change, and poor farming methods also lead to starvation, which in turn promotes social disruption. Famine has been common in parts of Africa since the 1980s, as illustrated by gifts of food from aid agencies.

(*Source:* World Population Data Sheet [Washington, DC: Population Reference Bureau, 2007. Accessed 5/19/08 @www.prb.org].)

FIGURE 1.6 Underweight children under the age of five by region. Most are in low- and middle-income countries.

low- and moderate-income countries are experiencing a serious crisis. In 2007 and 2008, food riots occurred in many locations, including Mexico, Haiti, Egypt, Yemen, Bangladesh, India, and Sudan (Figure 1.7). The rising cost of oil used to produce food (in fertilizer, transportation, working fields, etc.) and the conversion of some corn production to biofuels have been blamed. This situation involves yet another key theme: science and values. Scientific knowledge has led to increased agricultural production and to a better understanding of population growth and what is required to conserve natural resources. With this knowledge, we are forced to confront a choice: which is more important, the survival of people alive today or conservation of the environment on which future food production and human life depend?[10]

Answering this question requires both *value judgments* and the information and knowledge with which to make such judgments. For example, we must determine whether we can continue to increase agricultural production without destroying the very environment on which agriculture and, indeed, the persistence of life on Earth depend. Put another way, a technical, scientific investigation provides a basis for a value judgment.

Human Population and the Incidence of Natural Disasters

It is difficult to pick up a paper without hearing about a natural disaster striking some part of the world. It might be tornadoes in the midwestern United States, flooding in China or Indonesia, a tsunami in Japan, or hurricanes and typhoons around various locations in the Pacific and Atlantic oceans. What is clear is that the number of natural events has not dramatically increased, but the impacts certainly have. Going back a few hundred years, human population on Earth was much less, and when hazardous events struck an area, there was less chance of loss of structures and lives. As human population has grown, more people are in harm's way. A disaster that occurred before the planet was widely populated might have affected a few people in a small, isolated community. Today, a similar natural event is likely to be a catastrophe in which damages may exceed billions of dollars and take hundreds of lives (Figure 1.8). And with growing human population, more people are forced to live on marginal lands where hazardous events are more likely to occur. Thus, increasing population and poor land-use choices (some of which

Thony Belizaire/AFP/Getty Images, Inc.

(a) (b)

STRDEL/AFP/Getty Images, Inc.

FIGURE 1.7 Food riots over the rising cost of food in 2007. (a) Haiti and **(b)** Bangladesh.

REUTERS/MAINCHI SHIMBUN LANDOV

FIGURE 1.8 Tsunami waves in 2011 produced by a very large offshore earthquake inundating part of east coastal Japan (about 400 km or 250 miles north of Tokyo). More than 20,000 people died, and entire coastal communities were destroyed. High population density of about 300 people per square kilometer (800 per square mile) was achieved during the 19th and early 20th centuries, contributing to the large loss of life in the hazardous coastal zone where very large tsunamis happen about every 1,000 years.

are difficult to avoid) are leading to greater property damage and loss of life.

The Age of Abundance and Human Population Increase

Human population on Earth is increasing exponentially (see Working it Out 4.2 on exponential growth in Chapter 4), and on one hand, the general consensus is that this growth is not sustainable from a resource perspective. On the other hand, it has been argued that, along with the exponential growth of population, there has been an exponential growth of technology that has resulted in a much improved environment for people. The idea is that, as population continues to increase, people have a greater chance of making important innovations that will eventually provide clean water and energy on Earth, with affordable housing and education and good health care for all citizens.[11]

Let's explore this hypothesis in more detail. A lot of research has been done on innovation and what makes for creative environments. It certainly appears that large numbers of people working collaboratively in urban centers are more productive, and innovation and creativity occur at higher rates in cities. Thus, it appears that, as the urban regions have grown, so have technological advances and creativity. However, this is not true across the board, particularly for developing countries where the increase in population is most apparent and where large urban regions are developing.

Our large urban centers must provide a quality environment for people to be truly successful. Certainly, people move to large cities for economic reasons. There, even in the developing world, they will find more jobs and better health care. However, the apparent relationship between population and technology may not be so clear cut. Certainly, urban centers in developed countries with high-quality research labs and many people working collaboratively may experience an increased rate of inventions, innovations, and creative activity. This does not mean that there would be a similar increase in large urban areas where most of the population is just at or beyond the subsistence level. What might be said is that as urban centers in the developing world become more connected to the greater world through the Internet and other technology, they might be able to move forward more quickly. However, an ever-growing human population that exceeds the ability of the planet to support it will eventually lead to a failure of ecosystems and cause problems for humans. Later in this chapter and in Chapter 22 on urban environments, we will return to this discussion when we consider the principle that we live in an urban world.

1.3 Sustainability and Carrying Capacity

The story of recent famines and food crises brings up one of the central environmental questions of our day: What is the maximum number of people the Earth can sustain? That is, what is the sustainable human carrying capacity of the Earth? Much of this book will deal with information that helps answer this question. However, there is little doubt that we are using many renewable environmental resources faster than they can be replenished—in other words, we are using them *unsustainably*. In general, we are using forests and fish faster than they can regrow, and we are eliminating habitats of endangered species and other wildlife faster than they can be replenished. We are also extracting minerals, petroleum, and groundwater without sufficient concern for their limits or the need to recycle them. As a result, there is a shortage of some resources and a probability of more shortages in the future. Clearly, we must learn how to sustain our environmental resources so that they continue to provide benefits for people and other living things on our planet.[3]

Sustainability: The Environmental Objective

The environmental catchphrase of the 1990s was "saving our planet." Are all life and the environments on which life depends really in danger? Will we leave behind a dead planet?

In the long view of planetary evolution, it is certain that planet Earth will survive us. Our sun is likely to last another several billion years, and if all humans became extinct in the next few years, life would still flourish here on Earth. The changes we have made—in the landscape, the atmosphere, the waters—would last for a few hundred or thousands of years but in a modest length of time would be erased by natural processes. What we are concerned with, as environmentalists, is the quality of the *human* environment on Earth, for us today and for our children.

Environmentalists agree that sustainability must be achieved, but we are unclear about how to achieve it, in part because the word is used to mean different things, often leading to confusion that causes people to work at cross-purposes. **Sustainability** has two formal scientific meanings with respect to environment: (1) *sustainability of resources*, such as a species of fish from the ocean, a kind of tree from a forest, or coal from mines; and (2) *sustainability of an ecosystem*. Strictly speaking, harvesting a resource at a certain rate is sustainable if we can continue to harvest that resource at that same rate for some specified time well into the future. An ecosystem is sustainable if it can continue its primary functions for a specified time in the future. (Economists refer to the specified time in the future as a "planning time horizon.") Commonly, in discussions about environmental problems, the time period is not specified and is assumed to be very long—mathematically an infinite planning time, but in reality as long as it could possibly matter to us. For conservation of the environment and its resources to be based on quantitative science, both a rate of removal and a planning time horizon must be specified. However, ecosystems and species are always undergoing change, and a completely operational definition of *sustainability* will have to include such variation over time.

Economists, political scientists, and others also use the term *sustainability* in reference to types of development that are economically viable, do not harm the environment, and are socially just (fair to all people). We should also point out that the term *sustainable growth* is an oxymoron (i.e., a contradictory term) because any steady growth (fixed-percentage growth per year) produces large numbers in modest periods of time (see Working it Out 4.2 on exponential growth in Chapter 4).

One of the environmental paradigms of the 21st century will be sustainability, but how will it be attained? Economists have begun to consider what is known as the *sustainable global economy:* the careful management and wise use of the planet and its resources, analogous to the management of money and goods. Those focusing on a sustainable global economy generally agree that under present conditions the global economy is *not* sustainable. Increasing numbers of people have resulted in so much pollution of the land, air, and water that the ecosystems that people depend on are in danger of collapse. What, then, are the attributes of a sustainable economy in the information age?[12]

- Populations of humans and other organisms living in harmony with the natural support systems, such as air, water, and land (including ecosystems)
- An energy policy that does not pollute the atmosphere, cause climate change (such as global warming), or pose unacceptable risk (a political or social decision)
- A plan for renewable resources—such as water, forests, grasslands, agricultural lands, and fisheries—that will not deplete the resources or damage ecosystems
- A plan for nonrenewable resources that does not damage the environment, either locally or globally, and ensures that a share of our nonrenewable resources will be left to future generations
- A social, legal, and political system that is dedicated to sustainability, equity, and justice for all people, with a democratic mandate to produce such an economy

Recognizing that population is *the* environmental problem, we should keep in mind that a sustainable global economy will not be constructed around a completely stable global population. Rather, such an economy will take into account the fact that the size of the human population will fluctuate within some stable range necessary to maintain healthy relationships with other components of the environment. To achieve a sustainable global economy, we need to do the following:[12]

- Develop an effective population-control strategy. This will at least require more education of people, since literacy and population growth are inversely related.
- Completely restructure our energy programs. A sustainable global economy is probably impossible if it is based on the use of fossil fuels. New energy plans will be based on an integrated energy policy, with more emphasis on renewable energy sources (such as solar and wind) and on energy conservation.
- Institute economic planning, including a tax structure that will encourage population control and wise use of resources. Financial aid for developing countries is absolutely necessary to narrow the gap between rich and poor nations.
- Implement social, legal, political, and educational changes that help to maintain a quality local, regional, and global environment. This must be a serious commitment that all the people of the world will cooperate with.

Moving Toward Sustainability: Some Criteria

Stating that we wish to develop a sustainable future acknowledges that our present practices are not sustainable. Indeed, continuing on our present paths of overpopulation, resource consumption, and pollution will not lead to sustainability. We will need to develop new concepts that