Key Themes in Environmental Sciences

LEARNING OBJECTIVES

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

- That people and nature are intimately connected;
- Why rapid human population growth is the fundamental environmental issue;
- What sustainability is, and why we must learn to sustain our environmental resources;
- How human beings affect the environment of the entire planet;
- Why urban environments need attention;
- Why solutions to environmental problems involve making value judgments, based on scientific knowledge;
- What the precautionary principle is and why it is important.

Lions are a tourist attraction at Amboseli National Reserve in southern Kenya, and are a valuable resource. Massi people are beginning to help protect them, rather than hunt or poison them as they have traditionally done.
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CASE STUDY

Amboseli National Reserve: A Story of Change

Amboseli National Reserve in southern Kenya is home to the Maasai people, who are nomadic some of the time and raise cattle. The reserve is also a major tourist destination, where people from around the world can experience Africa and wild animals, such as lions and elephants. Today, environmental change and the future of tourism are being threatened in the area. We will consider long-term change and the more recent management of lions that may result in their local extinction.

Environmental change is often caused by a complex web of interactions among living things and between living things and their environment. In seeking to determine what caused a particular change, the most obvious answer may not be the right answer. Amboseli National Reserve is a case in point. In the short span of a few decades, this reserve, located at the foot of Mount Kilimanjaro (Figure 1.1), underwent a significant environmental change.

Before the mid-1950s, fever-tree woodlands—mostly acacia trees and associated grasses and shrubs—dominated the land and provided habitat for mammals that lived in these open woodlands, such as kudu, baboons, vervet monkeys, leopards, and impalas. Then, beginning in the 1950s and accelerating in the 1960s, these woodlands disappeared and were replaced by short grass and brush, which provided habitat for typical plains animals, such as zebras and wildebeest. Since the mid-1970s, Amboseli has remained a grassland with scattered brush and few trees.

Loss of the woodland habitat was initially blamed on overgrazing of cattle by the Maasai people (Figure 1.2) and damage to the trees from elephants (Figure 1.3). Environmental scientists eventually rejected these hypotheses as the main causes of the environmental change. Their careful work showed that changes in rainfall and soils were the primary culprits, rather than people or elephants.1, 2 How did they arrive at this explanation?

During recent decades, the mean daily temperature rose dramatically, and annual rainfall increased but continued to vary from year to year by a factor of four, though with no regular pattern.1, 2 Increased rainfall is generally associated with an increased abundance of trees, unlike what happened at Amboseli.

Why did scientists reject the overgrazing and elephant-damage hypothesis as the sole explanation for changes in Amboseli? Investigators were surprised to note that most dead trees were in an area that had been free of cattle since 1961, which was before the major decline in the woodland environment. Furthermore, some of the woodlands that suffered the least decline had the highest density of people and cattle. These observations suggested that overgrazing by cattle was not responsible for loss of the trees.

Elephant damage was thought to be a major factor because elephants had stripped bark from more than 83% of the trees in some areas and had pushed over some younger, smaller trees. However, researchers concluded that elephants played only a secondary role in changing the habitat. As the density of fewer trees and other woodland plants decreased, the incidence of damage caused by elephants increased. In other words, elephant damage interacted with some other, primary factor in changing the habitat.1

Figure 1.1 shows the boundary of the reserve and the major geologic units. The park is centered on an ancient lakebed, remnants of which include the seasonally flooded Lake Amboseli and some swampland. Mount Kilimanjaro is a well-known volcano, composed of alternating layers of volcanic rock and ash deposits. Rainfall that reaches the slopes of Mount Kilimanjaro infiltrates the volcanic material (becomes groundwater) and moves slowly down the slopes to saturate the ancient lakebed, eventually emerging at springs in the swampland, seasonally flooded land. The groundwater becomes saline (salty) as it percolates through the lakebed, since the salt stored in the lakebed sediments dissolves easily when the sediments are wet.

Because a lot of land has been transformed to agricultural uses, the slopes of Mount Kilimanjaro above Amboseli have less forest cover than they did 25 years ago. The loss of trees exposed dark soils that absorb solar energy, and this could cause local warming and drier conditions. In addition, there had been a significant decrease in snow and ice cover on the high slopes and summit of the mountain. Snow and ice reflect sunlight. As snow and ice decrease and dark rock is exposed, more solar energy is absorbed at the surface, warming it. Therefore, decreased snow and ice might cause some local warming.

Research on rainfall, groundwater history, and soils suggested that the area is very sensitive to changing amounts of rainfall. During dry periods, the salty groundwater sinks lower into the earth, and the soil near the surface has a relatively low salt content. The fever trees grow well in the nonsalty soil. During wet periods, the groundwater rises closer to the surface, bringing with it salt, which invades the root zones of trees and kills them. The groundwater level rose as much as 3.5 m (11.4 ft) in response to unusually wet years in the 1960s. Analysis of the soils confirmed that the tree stands that suffered the most damage were those growing in highly saline soils. As the trees died, they were replaced by salt-tolerant grasses and low brush.

Evaluation of the historical record—using information from Maasai herders recorded by early European explorers—and of fluctuating lake levels in other East African lakes suggested that before 1890 there had been another period of above-normal rainfall and loss of woodland environment. Thus, the scientists concluded that cycles of greater and lesser rainfall change hydrology and soil conditions, which in turn change the plant and animal life of the area. Cycles of wet and dry periods can be expected to continue, and associated with these will be changes in the soils, distribution of plants, and abundance and types of animals present.

Management by the Maasai is proving difficult. Tourists want to see wild lions, but the lions sometimes kill and eat Maasai cattle, so the Maasai are killing the
lions. Spearing, a Maasai passage to manhood, remains the dominant way to do it: In recent years, of 20 lions killed, 17 were speared and 3 were poisoned (Figure 1.4). The poison also kills other animals that scavenge cattle, such as hyenas and vultures. Programs to pay the Maasai for cattle lost to lions have problems, so the killing continues. Over 100 lions have been killed in the past ten years, and in spite of declining lion populations, the killing is still increasing. If it doesn’t stop, lions may become locally extinct in the reserve, which will damage tourism which brings much needed cash to the reserve. As a result, some Massi are now protecting lions and thus the tourist income (see opening photograph). It may come down to a value judgment: lions on the one hand and cattle and people on the other. The lions may also be threatened by a loss of grasslands if the climate continues to change and becomes drier. Such a change favors woodlands, wherein the lion’s natural prey, such as zebras and wildebeest, are replaced by kudu, impalas, monkeys, and baboons.

The Amboseli story illustrates that many environmental factors operate together, and that causes of change can be subtle and complex. The story also illustrates how environmental scientists attempt to work out sequences of events that follow a particular change. At Amboseli, rainfall cycles change hydrology and soil conditions, which in turn change the vegetation and animals of the area, and these in turn impact the people living there. To understand what happens in natural ecosystems, we can’t just look for an answer derived from a single factor. We have to look at the entire environment and all of the factors that together influence what happens to life. In this chapter, we discuss some of the fundamental concepts of studying the environment in terms of several key themes that we will revisit at the end of each chapter.

1.1 Major Themes of Environmental Science

The study of environmental problems and their solutions has never been more important. Modern society in 2009 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) rise 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 40 years, to 6.8 billion people today. 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. 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:

- **Human population growth** (the environmental problem).
- **Sustainability** (the environmental goal).
- **A global perspective** (many environmental problems require a global solution).
- **An urbanizing world** (most of us live and work in urban areas).
- **People and nature** (we share a common history with nature).
- **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

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**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 with 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.
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 40 years the human population of the world more than doubled, from 2.5 billion to about 6.8 billion. Figure 1.5 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 U.S. and Western Europe) is more than offset by rapid population growth in the developing regions (for example, Africa, India, and South America).

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 4, 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. 

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.

Famine and Food Crisis

Famine is one of the things 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. Starvation in African nations gained worldwide attention some ten years later, in the 1980s.

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 new. 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 1.6). 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 1.7).

Famines in Africa illustrate another key theme: people and nature. People affect the environment, and the environment affects people. The environment affects agriculture, and agriculture affects the environment. Human population growth in Africa has severely stretched the capacity of the land to provide sufficient food and has threatened its future productivity.

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 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 1.8). 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.

![Figure 1.5: Population growth in developed and developing nations, 1750 projected to 2100.](image-url)
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?\(^{13}\)

Answering this question demands 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.

The human population continues to grow, but humans’ effects on the environment are growing even faster.\(^ {14}\) People cannot escape the laws of population growth (this is discussed in several chapters). The broad science-and-values question is: What will we do about the increase in our own species and its impact on our planet and on our future?

FIGURE 1.6 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.

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1.3 Sustainability and Carrying Capacity

The story of recent famines and food crises brings up one of the central environmental questions: 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.

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, 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 Exponential Growth in Chapter 3).

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?15

- 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, 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 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:15

- 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 will mold industrial, social, and environmental interests into an integrated, harmonious system. In other words, we need to develop a new paradigm, an alternative to our present model for running society and creating wealth.16 The new paradigm might be described as follows.17

- **Evolutionary rather than revolutionary.** Developing a sustainable future will require an evolution in our values that involves our lifestyles as well as social, economic, and environmental justice.
- **Inclusive, not exclusive.** All peoples of Earth must be included. This means bringing all people to a higher standard of living in a sustainable way that will not compromise our environment.
- **Proactive, not reactive.** We must plan for change and for events such as human population problems, resource shortages, and natural hazards, rather than waiting for them to surprise us and then reacting. This may sometimes require us to apply the Precautionary Principle, which we discuss with science and values (Section 1.7).
- **Attracting, not attacking.** People must be attracted to the new paradigm because it is right and just. Those who speak for our environment should not take a hostile stand but should attract people to the path of sustainability through sound scientific argument and appropriate values.
- **Assisting the disadvantaged, not taking advantage.** This involves issues of environmental justice. All people have the right to live and work in a safe, clean environment. Working people around the globe need to receive a living wage—wages sufficient to support their families. Exploitation of workers to reduce the costs of manufacturing goods or growing food diminishes us all.
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The Carrying Capacity of the Earth

Carrying capacity is a concept related to sustainability. It is usually defined as the maximum number of individuals of a species that can be sustained by an environment without decreasing the capacity of the environment to sustain that same number in the future.

There are limits to the Earth’s potential to support humans. If we used Earth’s total photosynthetic potential with present technology and efficiency to support 6.8 billion people, Earth could support a human population of about 15 billion. However, in doing this, we would share our land with very little else.18, 19 When we ask “What is the maximum number of people that Earth can sustain?” we are asking not just about Earth’s carrying capacity but also about sustainability.

As we pointed out, what we consider a “desirable human carrying capacity” depends in part on our values (Figure 1.9). Do we want those who follow us to live short lives in crowded conditions, without a chance to enjoy Earth’s scenery and diversity of life? Or do we hope that our descendants will have a life of high quality and good health? Once we choose a goal regarding the quality of life, we can use scientific information to understand what the sustainable carrying capacity might be and how we might achieve it.

1.4 A Global Perspective

Our actions today are experienced worldwide. Because human actions have begun to change the environment all over the world, the next generation, more than the present generation, will have to take a global perspective on environmental issues (Figure 1.10).

Recognition that civilization can change the environment at a global level is relatively recent. As we discuss in detail in later chapters, scientists now believe that emissions of modern chemicals are changing the ozone layer high in the atmosphere. Scientists also believe that burning fossil fuels increases the concentration of greenhouse gases in the atmosphere, which may change Earth’s climate. These atmospheric changes suggest that the actions of many groups of people, at many locations, affect the environment of the entire world.20 Another new idea explored in later chapters is that not only human life but also nonhuman life affects the environment of our whole planet and has changed it over the course of several billion years. These two new ideas have profoundly affected our approach to environmental issues.

Awareness of the global interactions between life and the environment has led to the development of the Gaia hypothesis. Originated by British chemist James Lovelock and American biologist Lynn Margulis, the Gaia hypothesis (discussed in Chapter 3) proposes that over the

FIGURE 1.9 How many people do we want on Earth? (a) Streets of Calcutta; (b) Davis, California.

FIGURE 1.10 Earth from space. Isolated from other planets, Earth is “home,” the only habitat we have.
history of life on Earth, life has profoundly changed the global environment, and that these changes have tended to improve the chances for the continuation of life. Because life affects the environment at a global level, the environment of our planet is different from that of a lifeless one.

1.5 An Urban World

In part because of the rapid growth of the human population and in part because of changes in technology, we are becoming an urban species, and our effects on the environment are more and more the effects of urban life (Figure 1.11a). Economic development leads to urbanization; people move from farms to cities and then perhaps to suburbs. Cities and towns get larger, and because they are commonly located near rivers and along coastlines, urban sprawl often overtakes the agricultural land of river floodplains, as well as the coastal wetlands, which are important habitats for many rare and endangered species. As urban areas expand, wetlands are filled in, forests cut down, and soils covered over with pavement and buildings.

In developed countries, about 75% of the population live in urban areas and 25% in rural areas, but in developing countries only 40% of the people are city dwellers. By 2008, for the first time, more than half of the people on Earth lived in urban areas, and it is estimated that by 2025 almost two-thirds of the population—5 billion people—will live in cities. Only a few urban areas had populations

![Figure 1.11 (a) An urban world and a global perspective. When the United States is viewed at night from space, the urban areas show up as bright lights. The number of urban areas reflects the urbanization of our nation. (b) Megacities by 2015. (Source: Data from United Nations Population Division, World Urbanization 2005, and State of the World 2007. World Watch Institute.]

Source: United Nations
over 4 million in 1950. In 1999 Tokyo, Japan, was the world’s largest city, with a population of about 12 million, and by 2015 Tokyo will likely still be the world’s largest city, with a projected population of 28.9 million. The number of megacities—urban areas with at least 10 million inhabitants—increased from 2 (New York City and London) in 1950 to 22 (including Los Angeles and New York City) in 2005 (Figures 1.11b and 1.12). Most megacities are in the developing world, and it is estimated that by 2015 most megacities will be in Asia.21, 22

In the past, environmental organizations often focused on nonurban issues—wilderness, endangered species, and natural resources, including forests, fisheries, and wildlife. Although these will remain important issues, in the future we must place more emphasis on urban environments and their effects on the rest of the planet.

1.6 People and Nature

Today we stand at the threshold of a major change in our approach to environmental issues. Two paths lie before us. One path is to assume that environmental problems are the result of human actions and that the solution is simply to stop these actions. Based on the notion, popularized some 40 years ago, that people are separate from nature, this path has led to many advances but also many failures. It has emphasized confrontation and emotionalism and has been characterized by a lack of understanding of basic facts about the environment and how natural ecological systems function, often basing solutions instead on political ideologies and ancient myths about nature.

The second path begins with a scientific analysis of an environmental controversy and leads from there to cooperative problem solving. It accepts the connection between people and nature and offers the potential for long-lasting, successful solutions to environmental problems. One purpose of this book is to take the student down the second pathway.

People and nature are intimately integrated. Each affects the other. We depend on nature in countless ways. We depend on nature directly for many material resources, such as wood, water, and oxygen. We depend on nature indirectly through what are called public-service functions. For example, soil is necessary for plants and

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**FIGURE 1.12** An aerial photo of Los Angeles shows the large extent of a megacity.

**FIGURE 1.13** (a) Cross section of a soil; (b) earthworms are among the many soil animals important to maintaining soil fertility and structure.
therefore for us (Figure 1.13); the atmosphere provides a climate in which we can live; the ozone layer high in the atmosphere protects us from ultraviolet radiation; trees absorb some air pollutants; wetlands can cleanse water. We also depend on nature for beauty and recreation—the needs of our inner selves—as people always have.

We in turn affect nature. For as long as we have had tools, including fire, we have changed nature, often in ways that we like and have considered “natural.” One can argue that it is natural for organisms to change their environment. Elephants topple trees, changing forests to grasslands, and people cut down trees and plant crops (Figure 1.14). Who is to say which is more natural? In fact, few organisms do not change their environment.

People have known this for a long time, but the idea that people might change nature to their advantage was unpopular in the last decades of the 20th century. At that time, the word environment suggested something separate—“out there”—implying that people were not part of nature. Today, environmental sciences are showing us how people and nature connect, and in what ways this is beneficial to both.

With growing recognition of the environment’s importance, we are becoming more Earth-centered. We seek to spend more time in nature for recreation and spiritual activities. We accept that we have evolved on and with the Earth and are not separate from it. Although we are evolving fast, we remain genetically similar to people who lived more than 100,000 years ago. Do you ever wonder why we like to go camping, to sit around a fire at night roasting marshmallows and singing, or exchanging scary stories about bears and mountain lions (Figure 1.15)? More than ever, we understand and celebrate our union with nature as we work toward sustainability.

Most people recognize that we must seek sustainability not only of the environment but also of our economic activities, so that humanity and the environment can persist together. The dichotomy of the 20th century is giving way to a new unity: the idea that a sustainable environment and a sustainable economy may be compatible, that people and nature are intertwined, and that success for one involves success for the other.

1.7 Science and Values

Deciding what to do about an environmental problem involves both values and science, as we have already seen. We must choose what we want the environment to be. But to make this choice, we must first know what is possible. That requires knowing the scientific data and understanding its implications. Scientists rely on critical thinking. Critical scientific thinking is disciplined, using intellectual standards, effective communication, clarity, and commitment to developing scientific knowledge and skills. It leads to conclusions, generalizations, and, sometimes, scientific theories and even scientific laws. Taken together, these comprise a body of beliefs that, at the present time, account for all known observations about a particular phenomenon. Some of the intellectual standards are as follows:

Selected Intellectual Standards

- **Clarity:** If a statement is unclear, you can’t tell whether it is relevant or accurate.
- **Accuracy:** Is a statement true? Can it be checked? To what extent does a measurement agree with the accepted value?
- **Precision:** The degree of exactness to which something is measured. Can a statement be more specific, detailed, and exact?
CHAPTER 1  Key Themes in Environmental Sciences

Relevance: How well is a statement connected to the problem at hand?

Depth: Did you deal with the complexities of a question?

Breadth: Did you consider other points of view or look at it from a different perspective?

Logic: Does a conclusion make sense and follow from the evidence?

Significance: Is the problem an important one? Why?

Fairness: Are there any vested interests, and have other points of view received attention?


Once we know our options, we can select from among them. What we choose is determined by our values. An example of a value judgment regarding the world’s human environmental problem is the choice between the desire of an individual to have many children and the need to find a way to limit the human population worldwide.

After we have chosen a goal based on knowledge and values, we have to find a way to attain that goal. This step also requires knowledge. And the more technologically advanced and powerful our civilization, the more knowledge is required. For example, current fishing methods enable us to harvest very large numbers of chinook salmon from the Columbia River, and public demand for salmon encourages us to harvest as many as possible. To determine whether chinook salmon are sustainable, we must know how many there are now and how many there have been in the past. We must also understand the processes of birth and growth for this fish, as well as its food requirements, habitat, life cycle, and so forth—all the factors that ultimately determine the abundance of salmon in the Columbia River.

Consider, in contrast, the situation almost two centuries ago. When Lewis and Clark first made an expedition to the Columbia, they found many small villages of Native Americans who depended in large part on the fish in the river for food (Figure 1.16). The human population was small, and the methods of fishing were simple. The maximum number of fish the people could catch probably posed no threat to the salmon, so these people could fish without scientific understanding of numbers and processes. (This example does not suggest that prescientific societies lacked an appreciation for the idea of sustainability. On the contrary, many so-called primitive societies held strong beliefs about the limits of harvests.)

The Precautionary Principle

Science and values come to the forefront when we think about what action to take about a perceived environmental problem for which the science is only partially known. This is often the case because all science is preliminary and subject to analysis of new data, ideas, and tests of hypotheses. Even with careful scientific research, it can be difficult, even impossible, to prove with absolute certainty how relationships between human activities and other physical and biological processes lead to local and global environmental problems, such as global warming, depletion of ozone in the upper atmosphere, loss of biodiversity, and declining resources. For this reason, in 1992 the Rio Earth Summit on Sustainable Development listed as one of its principles what we now call the Precautionary Principle. Basically, it says that when there is a threat of serious, perhaps even irreversible, environmental damage, we should not wait for scientific proof before taking precautionary steps to prevent potential harm to the environment.

The Precautionary Principle requires critical thinking about a variety of environmental concerns, such as the manufacture and use of chemicals, including pesticides, herbicides, and drugs; the use of fossil fuels and nuclear energy; the conversion of land from one use to another (for example, from rural to urban); and the management of wildlife, fisheries, and forests.

FIGURE 1.16  Native Americans fishing for salmon on the Columbia River.
One important question in applying the Precautionary Principle is how much scientific evidence we should have before taking action on a particular environmental problem. The principle recognizes the need to evaluate all the scientific evidence we have and to draw provisional conclusions while continuing our scientific investigation, which may provide additional or more reliable data. For example, when considering environmental health issues related to the use of a pesticide, we may have a lot of scientific data, but with gaps, inconsistencies, and other scientific uncertainties. Those in favor of continuing to use that pesticide may argue that there isn’t enough proof of its danger to ban it. Others may argue that absolute proof of safety is necessary before a new pesticide is used. Those advocating the Precautionary Principle would argue that we should continue to investigate but, to be on the safe side, should not wait to take cost-effective precautionary measures to prevent environmental damage or health problems. What constitutes a cost-effective measure? Certainly we would need to examine the benefits and costs of taking a particular action versus taking no action. Other economic analyses may also be appropriate.23, 24

The Precautionary Principle is emerging as a new tool for environmental management and has been adopted by the city of San Francisco (Figure 1.17) and the European Union. There will always be arguments over what constitutes sufficient scientific knowledge for decision making. Nevertheless, the Precautionary Principle, even though it may be difficult to apply, is becoming a common part of environmental analysis with respect to environmental protection and environmental health issues. It requires us to think ahead and predict potential consequences before they occur. As a result, the Precautionary Principle is a proactive, rather than reactive, tool—that is, we can use it when we see real trouble coming, rather than reacting after the trouble arises.

FIGURE 1.17  The city of San Francisco, with its scenic bayside environment, has adopted the Precautionary Principle.

Placing a Value on the Environment

How do we place a value on any aspect of our environment? How do we choose between two different concerns? The value of the environment is based on eight justifications: utilitarian (materialistic), ecological, aesthetic, recreational, inspirational, creative, moral, and cultural.

The utilitarian justification is that some aspect of the environment is valuable because it benefits individuals economically or is directly necessary to human survival. For example, conserving lions in Africa as part of tourism provides a livelihood for local people.

The ecological justification is that an ecosystem is necessary for the survival of some species of interest to us, or that the system itself provides some benefit. For example, a mangrove swamp (a type of coastal wetland) provides habitat for marine fish, and although we do not eat mangrove trees, we may eat the fish that depend on them. Also, the mangroves are habitat for many noncommercial species, some endangered. Therefore, conservation of the mangrove is important ecologically. Another example: Burning coal and oil adds greenhouse gases to the atmosphere, which may lead to a climate change that could affect the entire Earth. Such ecological reasons form a basis for the conservation of nature that is essentially enlightened self-interest.

Aesthetic and recreational justifications have to do with our appreciation of the beauty of nature and our desire to get out and enjoy it. For example, many people find wilderness scenery beautiful and would rather live in a world with wilderness than without it. One way we enjoy nature’s beauty is to seek recreation in the outdoors.

The aesthetic and recreational justifications are gaining a legal basis. The state of Alaska acknowledges that sea otters have an important recreational role in that people enjoy watching and photographing them in a wilderness setting. And there are many other examples of the aesthetic importance of the environment. When people mourn the death of a loved one, they typically seek out places with grass, trees, and flowers; thus we use these to beautify our graveyards. Conservation of nature can be based on its benefits to the human spirit, our “inner selves” (inspirational justification). Nature is also often an aid to human creativity (the creative justification). The creativity of artists and poets, among others, is often inspired by their contact with nature. But while nature’s aesthetic, recreational, and inspirational value is a widespread reason that people enjoy nature, it is rarely used in formal environmental arguments, perhaps in the belief that they might seem superficial justifications for conserving nature. In fact, however, beauty in their surroundings is of profound importance to people. Frederick Law Olmsted, the great American landscape planner, argued that plantings of vegetation provide medical, psychological, and social benefits and are essential to city life.18
Moral justification has to do with the belief that various aspects of the environment have a right to exist and that it is our moral obligation to help them, or at least allow them, to persist. Moral arguments have been extended to many nonhuman organisms, to entire ecosystems, and even to inanimate objects. The historian Roderick Nash, for example, wrote an article entitled “Do Rocks Have Rights?” that discusses such moral justification, and the United Nations General Assembly World Charter for Nature, signed in 1982, states that species have a moral right to exist.

Cultural justification refers to the fact that different cultures have many of the same values but also some different values with respect to the environment. This may also be in terms of specifics of a particular value. All cultures may value nature, but, depending on their religious beliefs, may value it in different degrees of intensity. For example, Buddhist monks when preparing ground for a building may pick up and move disturbed earthworms, something few others would do. Different cultures integrate nature into their towns, cities, and homes in different ways depending on their view of nature.

Analysis of environmental values is the focus of a new discipline, known as environmental ethics. Another concern of environmental ethics is our obligation to future generations: Do we have a moral obligation to leave the environment in good condition for our descendants, or are we at liberty to use environmental resources to the point of depletion within our own lifetimes?
The story of Easter Island has been used as an example of how people may degrade the environment as they grow in number, until eventually their overuse of the environment results in the collapse of the society. This story has been challenged by recent work. We will present what is known, and you should examine the case history critically. To help with this issue, look back to the list of intellectual standards useful in critical thinking.

Easter Island’s history spans approximately 800 to 1,500 years and illustrates the importance of science and the sometimes irreversible consequences of human population growth and the introduction of a damaging exotic species, accompanied by depletion of resources necessary for survival. Evidence of the island’s history is based on detailed studies by earth scientists and social scientists who investigated the anthropological record left in the soil where people lived and the sediment in ponds where pollen from plants that lived at different times was deposited. The goals of the studies were to estimate the number of people, their diet, and their use of resources. This was linked to studies of changes in vegetation, soils, and land productivity.

Easter Island lies about 3,700 km west of South America and 4,000 km from Tahiti (Figure 1.18a), where the people may have come from. The island is small, about 170 km², with a rough triangular shape and an inactive volcano at each corner. The elevation is less than about 500 m (1,500 ft) (Figure 1.18b), too low to hold clouds like those in Hawaii that bring rain. As a result, water resources are limited. When Polynesian people first reached it about 800–1,500 years ago, they colonized a green island covered with rich soils and forest. The small group of settlers grew rapidly, to perhaps over 10,000 people, who eventually established a complex society that was spread among a number of small villages. They raised crops and chickens, supplementing their diet with fish from the sea. They used the island’s trees to build their homes and to build boats. They also carved massive 8-meter-high statues from volcanic rock and moved them into place at various parts of the island using tree trunks as rollers (Figure 1.18b, c).

When Europeans first reached Easter Island in 1722, the only symbols of the once-robust society were the statues. A study suggested that the island’s population had collapsed in just a few decades to about 2,000 people because they had used up (degraded) the isolated island’s limited resource base.25, 26

At first there were abundant resources, and the human population grew fast. To support their growing population, they cleared more and more land for agriculture and cut more trees for fuel, homes, and boats—and for moving the statues into place. Some of the food plants they brought to the island didn’t survive, possibly because the voyage was too long or the climate unsuitable for them. In particular, they did not have the breadfruit tree, a nutritious starchy food source, so they relied more heavily on other crops, which required clearing more land for planting. The island was also relatively dry, so it is likely that fires for clearing land got out of control sometimes and destroyed even more forest than intended.25, 26

The cards were stacked against the settlers to some extent—but they didn’t know this until too late. Other islands of similar size that the Polynesians had settled did not suffer forest depletion and fall into ruin.25, 26 This isolated island, however, was more sensitive to change. As the forests were cut down, the soils, no longer protected by forest cover, were lost to erosion. Loss of the soils reduced agricultural productivity, but the biggest loss was the trees. Without wood to build homes and boats, the people were forced to live in caves and could no longer venture out into the ocean for fish.25

These changes did not happen overnight—it took more than 1,000 years for the expanding population to deplete its resources. Loss of the forest was irreversible: Because it led to loss of soil, new trees could not grow to replace the forests. As resources grew scarcer, wars between the villages became common, as did slavery, and perhaps even cannibalism.

Easter Island is small, but its story is a dark one that suggests what can happen when people use up the resources of an isolated area. We note, however, that some aspects of the above history of Easter Island have recently been challenged. New data suggest that people first arrived about 800 years ago, not 1,500; thus, much less time was available for people to degrade the land.27, 28 Deforestation certainly played a role in the loss of trees, and the rats that arrived with the Polynesians were evidently responsible for eating seeds of the palm trees, preventing regeneration. According to the alternative explanation of the island’s demise, the Polynesian people on the island at the time of European contact in 1722 numbered about 3,000; this may have been close to the maximum reached around the year 1350. Contact with Europeans introduced new diseases and enslavement, which reduced the population to about 100 by the late 1870s.27

Easter Island, also called Rapa Nui, was annexed by Chile in 1888. Today, about 3,000 people live on the island. Tourism is the main source of income; about 90% of the island is grassland, and thin, rocky soil is common. There have been reforestation projects, and about 5% of the island is now forested, mostly by eucalyptus plantations in the central part of the island. There are also fruit trees in some areas.
As more of the story of Easter Island emerges from scientific and social studies, the effects of resource exploitation, invasive rats, and European contact will become clearer, and the environmental lessons of the collapse will lead to a better understanding of how we can sustain our global human culture. However, the primary lesson is that limited resources can support only a limited human population.

Like Easter Island, our planet Earth is isolated in our solar system and universe and has limited resources. As a result, the world’s growing population is facing the problem of how to conserve those resources. We know it takes a while before environmental damage begins to show, and we know that some environmental damage may be irreversible. We are striving to develop plans to ensure that our natural resources, as well as the other living things we share our planet with, will not be damaged beyond recovery.

Critical Thinking Questions
1. What are the main lessons to take from Easter Island’s history?
2. People may have arrived at Easter Island 1,500 years ago or later, perhaps 800 years ago. Does the timing make a significant difference in the story? How?
3. Assuming that an increasing human population, introduction of invasive rats, loss of trees, the resulting soil erosion, and, later, introduced European diseases led to collapse of the society, can Easter Island be used as a model for what could happen to Earth? Why? Why not?
Six themes run through this text: the urgency of the population issue; the importance of urban environments; the need for sustainability of resources; the importance of a global perspective; people and nature; and the role of science and values in the decisions we face.

People and nature are intertwined. Each affects the other.

The human population grew at a rate unprecedented in history in the 20th century. Population growth is the underlying environmental problem.

Achieving sustainability, the environmental goal, is a long-term process to maintain a quality environment for future generations. Sustainability is becoming an important environmental paradigm for the 21st century.

The combined impact of technology and population multiplies the impact on the environment.

In an increasingly urban world, we must focus much of our attention on the environments of cities and the effects of cities on the rest of the environment.

Determining Earth’s carrying capacity for people and levels of sustainable harvests of resources is difficult but crucial if we are to plan effectively to meet our needs in the future. Estimates of Earth’s carrying capacity for people range from 2.5 to 40 billion, but about 15 billion is the upper limit with today’s technology. The differences in capacity have to do with the quality of life projected for people—the poorer the quality of life, the more people can be packed onto the Earth.

Awareness of how people at a local level affect the environment globally gives credence to the Gaia hypothesis. Future generations will need a global perspective on environmental issues.

Placing a value on various aspects of the environment requires knowledge and understanding of the science, but also depends on our judgments about the uses and aesthetics of the environment and on our moral commitments to other living things and to future generations.

The Precautionary Principle is emerging as a powerful new tool for environmental management.

**SUMMARY**

**Human Population**

What is more important: the quality of life of people alive today or the quality of life of future generations?

**Sustainability**

What is more important: abundant resources today—as much as we want and can obtain—or the availability of these resources for future generations?

**Global Perspective**

What is more important: the quality of your local environment or the quality of the global environment—the environment of the entire planet?

**Urban World**

What is more important: human creativity and innovation, including arts, humanities, and science, or the persistence of certain endangered species? Must this always be a trade-off, or are there ways to have both?
People and Nature

If people have altered the environment for much of the time our species has been on Earth, what then is “natural”?

Science and Values

Does nature know best, so that we never have to ask what environmental goal we should seek, or do we need knowledge about our environment, so that we can make the best judgments given available information?

KEY TERMS

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STUDY QUESTIONS

1. Why is there a convergence of energy, economics, and environment?
2. In what ways do the effects on the environment of a resident of a large city differ from the effects of someone living on a farm? In what ways are the effects similar?
3. Programs have been established to supply food from Western nations to starving people in Africa. Some people argue that such programs, which may have short-term benefits, actually increase the threat of starvation in the future. What are the pros and cons of international food relief programs?
4. Why is there an emerging food crisis that is different from any in the past?
5. Which of the following are global environmental problems? Why?
   (a) Growth of the human population.
   (b) Furbish’s lousewort, a small flowering plant found in the state of Maine and in New Brunswick, Canada. It is so rare that it has been seen by few people and is considered endangered.
   (c) The blue whale, listed as an endangered species under the U.S. Marine Mammal Protection Act.
   (d) A car that has air-conditioning.
   (e) Seriously polluted harbors and coastlines in major ocean ports.
6. How could you determine the carrying capacity of Earth?
7. Is it possible that sometime in the future all the land on Earth will become one big city? If not, why not? To what extent does the answer depend on the following:
   (a) global environmental considerations
   (b) scientific information
   (c) values


Leopold, A., *A Sand County Almanac* (New York: Oxford University Press, 1949). Perhaps, along with Rachel Carson’s *Silent Spring*, one of the most influential books of the post–World War II and pre–Vietnam War era about the value of the environment. Leopold defines and explains the land ethic and writes poetically about the aesthetics of nature.

