

1 The Environmental Challenges We Face

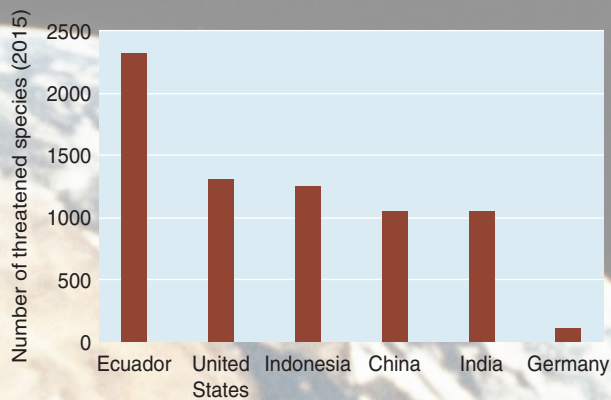
A RAPIDLY CHANGING WORLD

Over three billion years ago, just before the first life forms arose, Earth's surface and climate were inhospitable by modern standards, but contained abundant raw materials. Early life forms used the sun's energy to exploit Earth's resources. Over Earth's history, organisms have shaped the landscape, altered the global climate, and modified the chemical makeup of the ocean and soils. The environments found around the globe now reflect billions of years of change, and those environments will continue to change.

Today, humans are the dominant agent of environmental change on our planet, altering it more rapidly and in more ways than any other species ever has. We have developed technology to venture into space, allowing us a view of the uniqueness of our planet in the solar system (see photograph). However, our burgeoning population is overwhelming Earth's regenerative capacity. We have transformed forests, prairies, watersheds, ocean fisheries, and deserts. We consume ever-increasing amounts of Earth's abundant but finite resources—rich topsoil, clean water, and breathable air. Our activities have disrupted habitats of thousands upon thousands of other species. In 2015, the International Union for the Conservation of Nature classified 22,784 species worldwide as threatened (see insert).

Our activities impact Earth systems, including climate and nutrient cycles, from the local to the global level. What remains unclear is Earth's capacity to support a high quality of life for the billions of people who live on it now and will be born in the future. Making choices and policies to ensure human well-being requires that we understand Earth systems and how we change them.





Based on data from International Union for Conservation of Nature 2015. Red List of Endangered Species.

CHAPTER OUTLINE

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- The Gap Between Rich and Poor Countries
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CHAPTER PLANNER ✓

- ☐ Study the picture and read the opening story.
- ☐ Scan the Learning Objectives in each section:
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- ☐ Read the text and study all figures and visuals.
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Analyze key features

- ☐ Environmental InSight, p. 5 ☐ p. 13 ☐
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End of Chapter

- ☐ Review the Summary and Key Terms.
- ☐ Answer What is happening in this picture?
- ☐ Answer the Critical and Creative Thinking Questions.

Human Impacts on the Environment

LEARNING OBJECTIVES

1. **Distinguish** among highly developed countries, moderately developed countries, and less developed countries.
2. **Relate** human population size to natural resources and resource consumption.
3. **Describe** the three factors that are most important in determining human impact on the environment.

The satellite photograph in **Figure 1.1a** is a portrait of about 450 million people. The tiny specks of light represent cities, and the great metropolitan areas, such as New York City along the northeastern seacoast, are ablaze with light. This represents the most significant factor impacting the health of Earth's environment: a large and growing human population.

In 2015 the human population as a whole passed 7.3 billion individuals, and this growth has been very rapid. In 1960 the human population was only 3 billion (**Figure 1.1b**). By 1975 there were 4 billion people, and by 1987 there were 5 billion. The more than 7 billion people who currently inhabit our planet consume vast quantities of food and water, occupy or farm much of the most productive land, use a great deal of energy and raw materials, and produce much waste.

Despite most countries' involvement with family planning, population growth rates don't change overnight. Several billion people will be added to the world in the 21st century, so even if we remain concerned about population and even if our solutions are very effective, the coming decades may very well see many problems.

Globally, about 1.5 billion individuals live in multidimensional **poverty** (**Figure 1.1c**). While poverty can be measured by income alone, multidimensional poverty includes such factors as income, access to education, and local environmental quality. Poverty is associated with a short life expectancy, illiteracy, and inadequate access to health services, safe water, and balanced nutrition. Worldwide,

poverty is decreasing, but remains sensitive to environmental degradation.

The world population may stabilize toward the end of the 21st century, driven by policy and cultural factors. Population experts at the Population Reference Bureau have noticed a decrease in the fertility rate worldwide to a current average of 2.5 children per woman, and the fertility rate is projected to continue to decline in coming decades.

The fertility rate varies from country to country, from 1.7 in highly developed countries to 4.5 in some of the least developed countries. Population experts have made various projections for the world population at the end of the 21st century, from about 7.7 billion to 10.6 billion, depending primarily on how fast the fertility rate decreases.

No one knows whether Earth can support so many people indefinitely. Finding ways for it to do so represents one of the greatest challenges of our times. Among the tasks to be accomplished is feeding a world population considerably larger than today's without destroying the biological communities that support life on our planet. The quality of life available to our children and grandchildren will depend to a large extent on our ability to develop a sustainable system of agriculture to feed the world's people.

A factor as important as population size is a population's level of **consumption**, which is the human use of material and energy. Consumption is intimately connected to a country's **economic growth**, the expansion in output of a nation's goods and services. The world's economy is growing at an enormous rate, yet this growth is unevenly distributed across the nations of the world.

poverty A condition in which people are unable to meet their basic needs for food, clothing, shelter, education, or health.

highly developed countries Countries with complex industrialized bases, low rates of population growth, and high per person incomes.

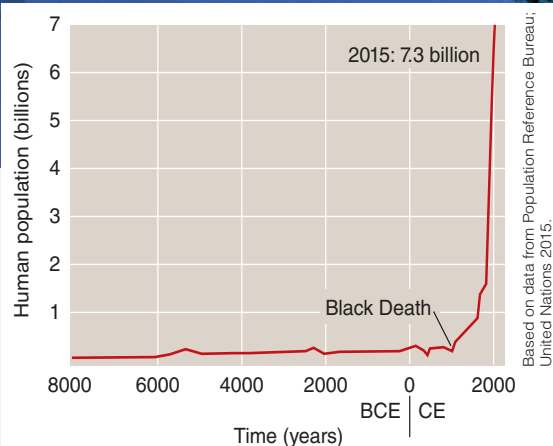
The Gap Between Rich and Poor Countries

Generally speaking, countries are divided into rich (the "haves") and poor (the "have-nots"). Rich countries are known as **highly developed countries**. The United States, Canada, most of Europe, and Japan, which represent about

Earth Imaging/Stone/Getty Images



Many of the world's poor people lack access to adequate sanitation, cooking and heating fuel, clean drinking water, health care, suitable housing, and enough food. Which two of these inadequacies would be most critical for poor people in a developing country like India? For poor people in a highly developed country like the United States? Are your answers different? Why or why not?



b. Human Population Growth.

It took thousands of years for the human population to reach 1 billion (in 1800). In 2015, Earth's human population surpassed 7 billion. (Black Death refers to a devastating disease, probably bubonic plague, that decimated Europe and Asia in the 14th century.)

a. Satellite View of North America at Night.

This image shows most major cities and metropolitan areas in the United States, Mexico, and Canada.



M. Lourdes Siracusa Cappel/mtsiraci/Flickr/Getty Images Inc

c. Poverty.

While Brazil's economy has developed substantially over the past decade, many residents continue to live in deep poverty in favelas (slums) like this one near São Paulo. Note the luxury hotels in the background.



a. A typical Japanese family, from Tokyo, with their possessions. People in highly developed countries consume a disproportionate share of natural resources.



b. A typical Mexican family, from Guadalajara, with their possessions. Economic development in this moderately developed country has allowed many people to enjoy a middle-class lifestyle. Other Mexicans live in poverty, however.

18 percent of the world's population, are highly developed countries (**Figure 1.2a**).

Poor countries, in which about 82 percent of the world's population live, fall into two subcategories: moderately developed and less developed. Turkey, South Africa, Thailand, and Mexico are examples of **moderately developed countries** (MDCs) (**Figure 1.2b**). People living in MDCs have fewer opportunities for income, education, and health care than people living in highly developed countries.

moderately developed countries

Countries with medium levels of industrialization and per person incomes lower than those of highly developed countries.

less developed countries

Countries with low levels of industrialization, very high rates of population growth, very high infant mortality rates, and very low per person incomes relative to highly developed countries.

Examples of **less developed countries** (LDCs) include Haiti, Bangladesh, Rwanda, Laos, Ethiopia, and Mali (**Figure 1.2c**). Cheap, unskilled labor is abundant in LDCs, but capital for investment is scarce. To improve their economic conditions, many LDCs must borrow money from banks in highly developed countries. Most economies of LDCs are agriculturally based, often relying on only one or a few crops. As a result, crop failure or a low

world market value for that crop is catastrophic to the economy. Hunger, disease, and illiteracy are common in LDCs.

Population, Resources, and the Environment

Inhabitants of the United States and other highly developed countries consume many more resources per person than do citizens of developing countries. This high rate of resource consumption affects the environment at least as much as the rapid population growth that is occurring in other parts of the world. China and India, the world's most populous countries, include many of the world's poorest people, a growing middle class, and a few of the world's wealthiest people. Both countries have growing populations and expanding economies.

We can make two useful generalizations about the relationships among population growth, consumption of natural resources, and environmental degradation. First, the amount of resources essential to an individual's survival is small, but rapid population growth (often found in developing countries) tends to overwhelm and deplete a country's soils, forests, and other natural resources. Second, in highly developed nations, individual demands



© Peter Menzel / menzelphoto.com

c. A typical family from Kouakourou, Mali, with all their possessions. The rapidly increasing number of people in less developed countries overwhelms their natural resources, even though individual resource requirements may be low.

on natural resources are far greater than the requirements for mere survival. To satisfy their desires as well as their basic needs, many people in more affluent nations deplete resources and degrade the global environment through increased consumption of energy (through such uses as heating, transportation, and manufacturing), material goods (such as cars, televisions, and cellular phones), and agricultural products (including food, animal feed, and wood products). An increase in urban agriculture in highly developed countries is an example of a local solution to this sort of problem (see *Enviro-Discovery* 1.1).

Types of Resources When examining the effects of population on the environment, it is important to distinguish between nonrenewable and renewable natural resources. **Nonrenewable resources** include minerals (such as silicon, iron, and copper) and fossil fuels (coal, oil, and natural gas). Natural processes do not replenish nonrenewable resources within a reasonable duration on the human timescale. Fossil fuels, for example, take millions of years to form.

In addition to a nation's population and its level of resource use, several other factors affect the way nonrenewable resources are used—including how efficiently

the resource is extracted and processed and how much of it is required or consumed. Nonetheless, the inescapable fact is that Earth has a finite supply of nonrenewable resources that sooner or later will be exhausted. In time, technological advances may help find or develop substitutes for nonrenewable resources. Slowing the rate of population growth and resource consumption will help us buy time to develop such alternatives.

Some examples of **renewable resources** are trees, fishes, fertile agricultural soil, and fresh water. Nature replaces these resources fairly rapidly, on a scale of days to decades. Forests, fisheries, and agricultural land are particularly important renewable resources in developing countries because they provide food. Indeed, many people in developing countries are subsistence farmers who harvest just enough food for their families to survive.

renewable resources Resources that are replaced by natural processes and that can be used forever, provided they are not overexploited in the short term.

Rapid population growth can cause renewable resources to be overexploited. For example, large numbers of poor people must grow crops on land—such as mountain slopes or tropical rain forests—that is poorly suited for farming. Although this practice may provide a short-term solution to the need for food, it does not work in the long run because when these lands are cleared for farming, their agricultural productivity declines rapidly and severe environmental deterioration occurs. Renewable resources, then, are *potentially* renewable. They must be used in a manner that allows natural processes time to replace or replenish them.

The effects of population growth on natural resources are particularly critical in developing countries. The economic growth of developing countries is frequently tied to the exploitation of their natural resources, often for export to highly developed countries. Developing countries are faced with the difficult choice of exploiting natural resources to provide for their expanding populations in the short term (that is, to pay for food or to cover debts) or conserving those resources for future generations.

It is instructive to note that the economic growth and development of the United States and of other highly developed nations came about through the exploitation—and, in some cases, the destruction—of their resources. Continued growth and development in highly developed countries now relies significantly on the importation of these resources from less developed countries.

Poverty is tied to the effects of population pressures on natural resources and the environment. Poor

nonrenewable resources Natural resources that are present in limited supplies and are depleted as they are used.

EnviroDiscovery 1.1

Green Roofs

Green roof

The Jacob K. Javits Convention Center is one of many buildings in New York City with a living green roof.

Wang Lei/Xinhua Press/Corbis



A roof that is completely or partially covered with vegetation and soil is known as a *green roof*. Also called *eco-roofs*, green roofs can provide several environmental benefits. For one thing, the plants and soil are effective insulators, reducing heating costs in winter and cooling costs in summer. The rooftop mini-ecosystem filters pollutants out of rainwater and reduces the amount of stormwater draining into sewers. In urban areas, green roofs provide wildlife habitat, even on the tops of tall buildings. A city with multiple green roofs provides “stepping stones” of habitat that enable migrating birds and insects to pass unharmed through the city. Green roofs can also be used to grow vegetable and fruit crops and to provide an outdoor refuge for people living or working in the building.

Green roofs allow urban systems to more closely resemble the natural systems they have replaced and provide resources that would otherwise have to be brought in.

Green roofs may be added to existing buildings, but it is often easier and less expensive to install them in new buildings. Modern green roofs, which are designed to support the additional weight of soil and plants, consist of several layers that hold the soil in place, stop plant roots from growing through the rooftop, and drain excess water, thereby preventing leaks. New York City is one of many cities that have increasing numbers of green roofs (see photograph). One of the largest individual green roofs in the United States is on the Ford Motor Company Plant in Dearborn, Michigan.

communities in developing countries find themselves trapped in a vicious cycle of poverty. They use environmental resources for short-term gain (that is, to survive), but this exploitation degrades the resources and diminishes long-term prospects of economic development.

Population Size and Resource Consumption

Resource issues are clearly related to population size: At a given level of consumption, a larger population consumes more resources and causes more environmental damage than does a smaller population. However, not all people consume the same amounts of resources. Consumption patterns vary across different populations within a single country and among the different regions of the world.

Variation in consumption is associated with economic status, geography (especially whether people live in rural, suburban, or urban areas), culture, and other social and personal factors. A resident of a city who walks to work, rarely eats meat, owns few belongings, and has a small, well-insulated home may consume a fraction of the resources as a resident of nearby suburbs.

Consumption is both an economic and a social act. Consumption provides the consumer with a sense of identity as well as status among peers. The media, including the advertising industry, promote consumption as a way to achieve happiness. We are encouraged to spend, to consume.

People in highly developed countries can be extravagant and wasteful consumers; their use of resources is greatly out of proportion to their numbers. A single child born in a highly developed country such as the United States causes a greater impact on the environment and on resource depletion than perhaps 20 children born in a developing country. Many natural resources are needed to provide the automobiles, air conditioners, disposable diapers, cell phones, DVD players, computers, clothes, newspapers, athletic shoes, furniture, books, and other “comforts” of life in highly developed nations. Thus, the disproportionately large consumption of resources by the United States and other highly developed countries affects natural resources and the environment as much as or more than the population explosion in the developing world.

Highly developed nations represent less than 20 percent of the world’s population, yet they consume significantly more than half of its resources. According to the Worldwatch Institute, highly developed countries account for the lion’s share of total resources consumed:

- 86 percent of aluminum used
- 76 percent of timber harvested
- 68 percent of energy produced
- 61 percent of meat eaten
- 42 percent of the fresh water consumed

These nations also generate 75 percent of the world’s pollution and waste (**Figure 1.3**).

Consumption • Figure 1.3

American consumption is actively promoted in Times Square advertisements.

Highly developed nations, such as the United States, consume more than 50 percent of the world’s resources, produce 75 percent of its pollution and waste, and represent only 18 percent of its total population.



Raga Jose Fuste/Prisma/SuperStock

Ecological footprints Each person has an **ecological footprint**, an amount of productive land, fresh air and water, and ocean required on a continuous basis to supply that person with food, wood, energy, water, housing, clothing, transportation, and waste disposal. In the *Living Planet Report 2014*, scientists calculated that Earth has about 11.4 billion hectares (28.2 billion acres) of productive land and water. If we divide this area by the global human population, it indicates that each person is allotted about 1.8 hectares (4.3 acres). However, the average global ecological footprint is currently about 2.8 hectares (6.9 acres) per person, which means we have an *ecological overshoot*—we have depleted our allotment. We can see the short-term results around us—forest destruction, degradation of croplands, loss of biological diversity, declining ocean fisheries, local water shortages, and increasing pollution. The long-term outlook, if we do not seriously address our consumption of natural resources, is potentially disastrous.

The developing nation of India is the world's second largest country in terms of population, so even though its per capita footprint is low, the country's total footprint is high (**Figure 1.4**). In France, the per capita ecological footprint is high at 4.9 hectares (12.1 acres), but its footprint as a country is relatively low, at 298.1 million hectares (736.6 million acres). The United States, which has the world's third largest population, has a per capita ecological footprint of 9.4 hectares (23.3 acres); the U.S. footprint as a country is a whopping 2810 million hectares (6943 million acres). If all people in the world had the same lifestyle and level of consumption as the average American, and assuming no changes in technology, we would need four additional planets the size of Earth to support us all.

As developing nations increase their economic growth and improve their standard of living, they purchase more and more consumer goods. By the early 2000s, more new cars were sold annually in Asia than in North America and western Europe combined. These new consumers may not use as much as the average consumer in a highly developed nation, but their consumption increasingly impacts the environment. For example, air pollution from traffic in urban centers in developing countries is bad and getting worse every year. In 2014 the Organization for Economic Cooperation and Development estimated that air pollution costs about \$3.5 trillion each year, about half of which is from transportation.

Population, consumption, and environmental impact When you turn on the tap to brush your teeth in the morning,

you probably do not think about where the water comes from or about the environmental consequences of removing it from a river or the ground. All the materials that make up the products we use every day come from Earth, and these materials eventually are returned to Earth, mainly in sanitary landfills.

Such human impacts on the environment are difficult to assess. One way to estimate them is to consider the three factors most important in determining environmental impact (I):

- The number of people (P).
- The affluence per person, which is a measure of the consumption, or amount of resources used per person (A).
- The environmental effects (resources needed and wastes produced) of the technologies used to obtain and consume the resources (T).

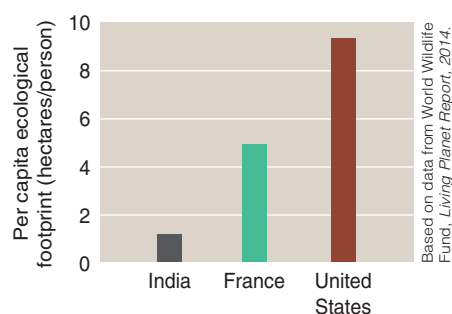
This method of assessment is usually referred to as the **IPAT model**: $I = P \times A \times T$.

Biologist **Paul R. Ehrlich** and physicist **John P. Holdren** first proposed the IPAT model in the 1970s. This equation describes the relationship between environmental impacts and the forces that drive them. To determine the environmental impact of carbon dioxide (CO₂) emissions from motor vehicles, for example, multiply the population by the number of cars per person (affluence or consumption per person) by the average annual CO₂ emissions per year (technological impact). This model demonstrates that although improving motor vehicle efficiency and developing cleaner technologies will reduce pollution and environmental degradation, a larger reduction will result if population and per person consumption are also controlled.

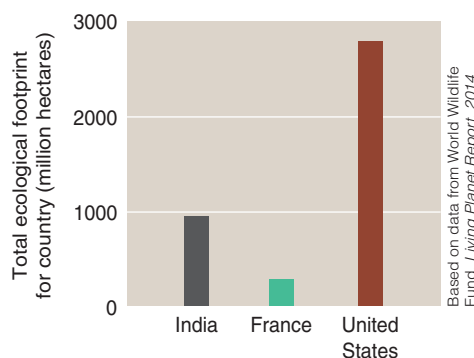
The three factors in the IPAT model are always changing in relation to each other. Generally, this model predicts that as population and affluence increase, environmental impacts will increase as well. However, technological improvements can reduce impacts. For example, flat-screen televisions contain less materials and require less energy to produce, transport, and operate than did typical televisions produced two decades ago.

The IPAT model helps to identify what we don't know or understand about consumption and its environmental impact. For example, which kinds of consumption have the greatest destructive impact on the environment? How can we alter the activities of these environmentally disruptive consumption patterns? What combination of technological advances and behavioral changes

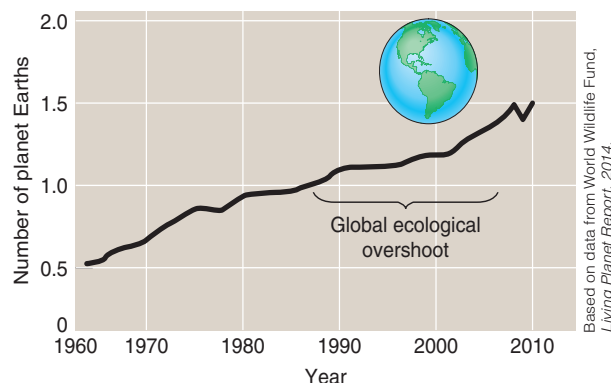
Ecological footprints • Figure 1.4



a. The average ecological footprint of a person living in India, France, or the United States. For example, the average Indian requires 0.9 hectare (2.2 acres) of productive land and ocean to meet his or her resource requirements.



b. The total ecological footprint for India, France, and the United States. Notice that India, although having a low per capita ecological footprint, has a relatively large total footprint as a country because of its large population. If everyone in the world had the same level of consumption as the average American, it would take the resources and area of five Earths.



c. Earth's ecological footprint has been increasing over time. By 2010, humans were using the equivalent of 1.5 Earths, a situation that is not sustainable.



Calculate your individual ecological footprint online. (Search for "ecological footprint.") Are you living sustainably? Suggest two things that you could do to lower your ecological footprint.

can create simultaneous improvements in economic, environmental, and social conditions? It will take years to address such questions, but the answers should help decision makers in business and government formulate policies that will alter consumption patterns in an environmentally responsible way. The ultimate goal should be to make consumption sustainable so that humanity's current practices do not compromise the ability of future generations to use and enjoy the riches of our planet.

To summarize, as human numbers and consumption increase worldwide, so does humanity's impact on Earth, posing new challenges to us all. Success in achieving sustainability in population size and consumption will require the cooperation of all the world's peoples.

CONCEPT CHECK



- How** do highly developed countries, moderately developed countries, and less developed countries differ regarding population growth and per person incomes?
- How** is human population growth related to natural resource depletion and environmental degradation?
- What** can the three factors of the IPAT model tell us about measuring and reducing harmful environmental impacts?

Sustainability and the Environment

LEARNING OBJECTIVES

1. **Define** sustainability.
2. **Identify** human behaviors that threaten environmental sustainability.

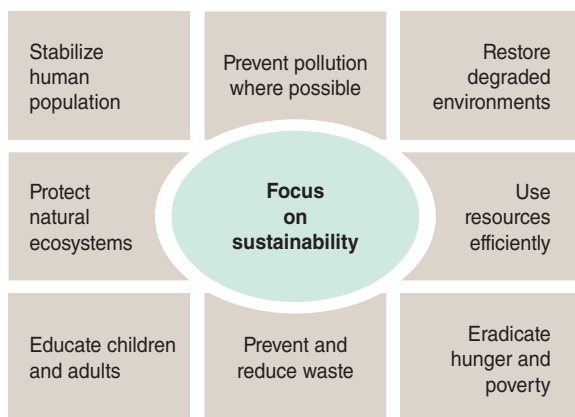
Sustainability is an organizing principle for this text. Sustainability is achieved when the environment can function indefinitely without going into a decline from the stresses that human society imposes on natural systems (such as fertile soil, water, and air) (Figure 1.5). Sustainability applies at many levels, including the individual, communal, regional, national, and global levels.

sustainability

The ability to meet humanity's current needs without compromising the ability of future generations to meet their needs.

Sustainability is based in part on the following ideas:

- We must think simultaneously about economic, social, and environmental well-being.
- We must consider the effects of our actions on the health and well-being of the natural environment, including all living things.
- Earth's resources are not present in infinite supply. We must live within limits that let renewable resources such as fresh water regenerate for future needs.



Focus on sustainability • Figure 1.5

Environmental sustainability requires a long-term perspective to promote economic, social, and environmental well-being, such as the goals shown here.

- We must understand all the costs to the environment and to society of products we consume.
- All of Earth's inhabitants share a responsibility for living sustainably.

Many environmental experts think that human society is not operating sustainably because of the following human behaviors (Figures 1.6 and 1.7):

- We are using nonrenewable resources such as fossil fuels as if they were present in unlimited supplies.
- We are using renewable resources such as fresh water and forests faster than they are replenished naturally.
- We are polluting the environment—the land, rivers, ocean, and atmosphere—with toxins as if the capacity of the environment to absorb them were limitless.
- Our numbers continue to grow, despite Earth's finite ability to feed us and to absorb our wastes.
- Our activities disrupt the ability of natural processes to regenerate; this happens from the local to the global scale.

If left unchecked, these activities may threaten the life-support systems of Earth to the extent that recovery is impossible. Our first goal should be to critically evaluate which changes our society is willing to make.

At first glance, issues of sustainability may seem simple. The solutions are more complex and challenging, in part because of various interacting ecological, societal, and economic factors. Our incomplete scientific understanding of how the environment works and how human choices affect the environment is a major reason that sustainability is difficult to achieve. Even for established environmental problems, political and social controversy often prevents widespread acceptance that an environmental threat is real.

CONCEPT CHECK



1. **What** is sustainability?
2. **Which** human behaviors threaten sustainability?

a. Harvesting Rare Fish. A worker prepares frozen giant bluefin tuna for auction at the Tsukiji market in Tokyo, Japan. These increasingly rare fish are caught around the globe.

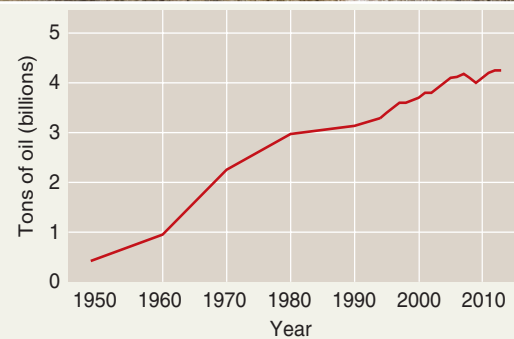
Keith Douglas/All Canada Photos/SuperStock



© AHowden/Japan Stock Photography/Alamy Limited



b. Clear Cutting. This section of forest in British Columbia, Canada, has been clear cut, leaving it vulnerable to erosion.



Based on data from U.S. Dept. of Energy Information Agency, World energy database.

d. Annual World Oil Consumption, 1950 to 2013.

World oil consumption dipped between 2007 and 2010 due to global economic recession.



Interpret the Data

By approximately how much did annual world oil consumption increase in the past 20 years? Is the increase sustainable? Why or why not?

Tom Bonaventure/Photographer's Choice/Getty Images

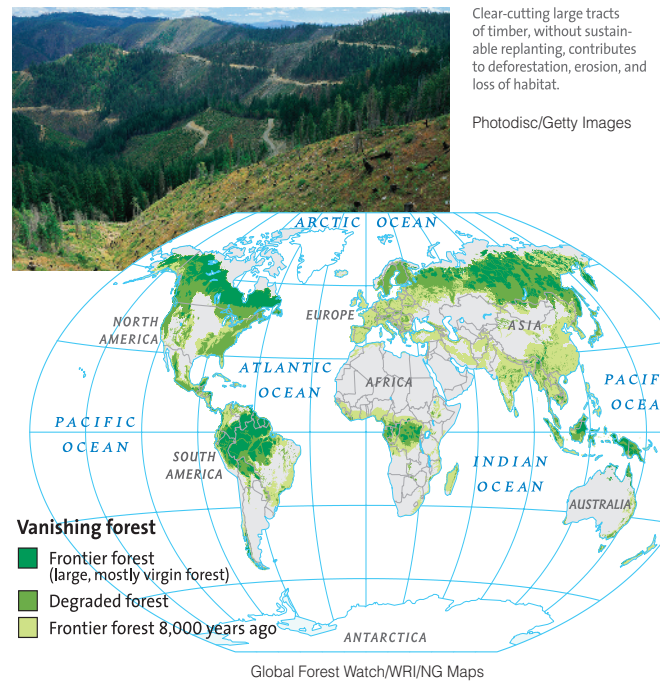
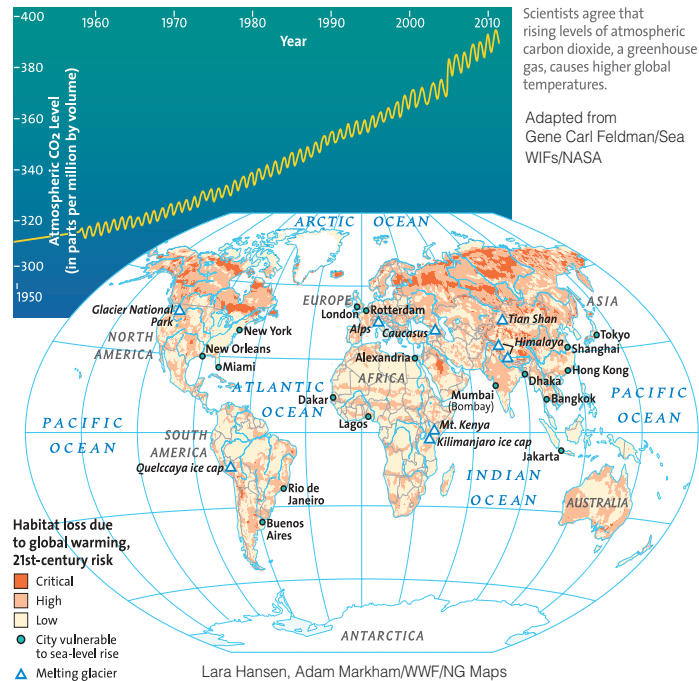
c. Oil Refinery at Grangemouth, United Kingdom.

Both highly developed and developing countries depend largely on oil for economic development.



Global environmental issues • Figure 1.7

These issues occur locally at so many places around the planet that they are global in scope.



▲ GLOBAL WARMING

Temperatures across the world are increasing at a rate not seen at any other time in the last 10,000 years. Although climate variation is a natural phenomenon, human activities that release carbon dioxide and other greenhouse gases into the atmosphere—industrial

processes, fossil fuel consumption, deforestation, and land use change—are the primary cause of this warming trend. Scientists predict that if this trend continues, one-third of plant and animal habitats will be dramatically altered and more than one million

species will be threatened with extinction in the next 50 years. And even small increases in global temperatures can melt glaciers and polar ice sheets, raising sea levels and flooding coastal cities and towns.

▲ DEFORESTATION

Of the 13 million hectares (32 million acres) of forest lost each year, mostly to make room for agriculture, more than half are in South America and Africa, where many of the world's tropical rain forests and terrestrial

plant and animal species can be found. Loss of habitat in such species-rich areas takes a toll on the world's biodiversity. Deforested areas also release, instead of absorb, carbon dioxide into the atmosphere, contribut-

ing to global climate change. Deforestation can also affect local climates by reducing evaporative cooling, leading to decreased rainfall and higher temperatures.



Linked to pollution, black band disease kills a coral head near the island of Curaçao.

Caroline Rogers/USGS



▲ THREATENED OCEANS

Oceans cover more than two-thirds of the Earth's surface and are home to at least half of the world's biodiversity, yet they are the least understood ecosystems. The combined

stresses of overfishing, pollution, increased carbon dioxide emissions, global climate change, and coastal development are having a serious impact on the health of oceans and ocean species.

Over 70% of the world's fish species are depleted or nearing depletion, and 50% of coral reefs worldwide are threatened by human activities.



In China's Tengger Desert, sand threatens to engulf nearby railroad lines despite a grid of straw meant to help stabilize the drifts.

Bruce Dale/NG Image Collection

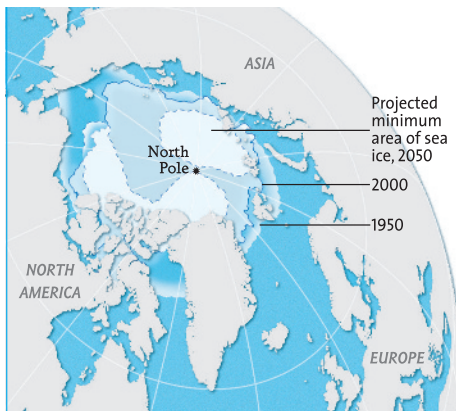


▲ DESERTIFICATION

Climate variability and human activities, such as grazing and conversion of natural areas to agricultural use, are leading causes of desertification, the degradation of land in arid, semiarid,

and dry subhumid areas. The environmental consequences of desertification are great—loss of topsoil, increased soil salinity, damaged vegetation, regional climate change, and a

decline in biodiversity. Equally critical are the social consequences—more than 2 billion people live in and make a living off these dryland areas, covering about 41% of Earth's surface.



▲ POLAR ICE CAP
Over the last 50 years, the extent of polar sea ice has noticeably decreased. Since 1970 alone, an area larger than Norway, Sweden, and

Denmark combined has melted. This trend is predicted to accelerate as temperatures rise in the Arctic and across the globe.

National/Naval Ice Center/NG Maps

GeoBytes

ACIDIFYING OCEANS

Oceans are absorbing an unprecedented 20 to 25 million tonnes (22 to 28 million tons) of carbon dioxide each day, increasing the water's acidity.

ENDANGERED REEFS

Some 95% of coral reefs in Southeast Asia have been destroyed or are threatened.

RECORD TEMPERATURES

The 1990s were the warmest decade on record in the last century.

WARMING ARCTIC

While the world as a whole has warmed nearly 0.6°C (1°F) over the last hundred years, parts of the Arctic have warmed 4 to 5 times as much in only the last 50 years.

DISAPPEARING RAIN FORESTS

Scientists predict that the world's rain forests will disappear within the next 100 years if the current rate of deforestation continues.

OIL POLLUTION

Nearly 1.3 million tonnes (1.4 million tons) of oil seep into the world's oceans each year from the combined sources of natural seepage, extraction, transportation, and consumption.

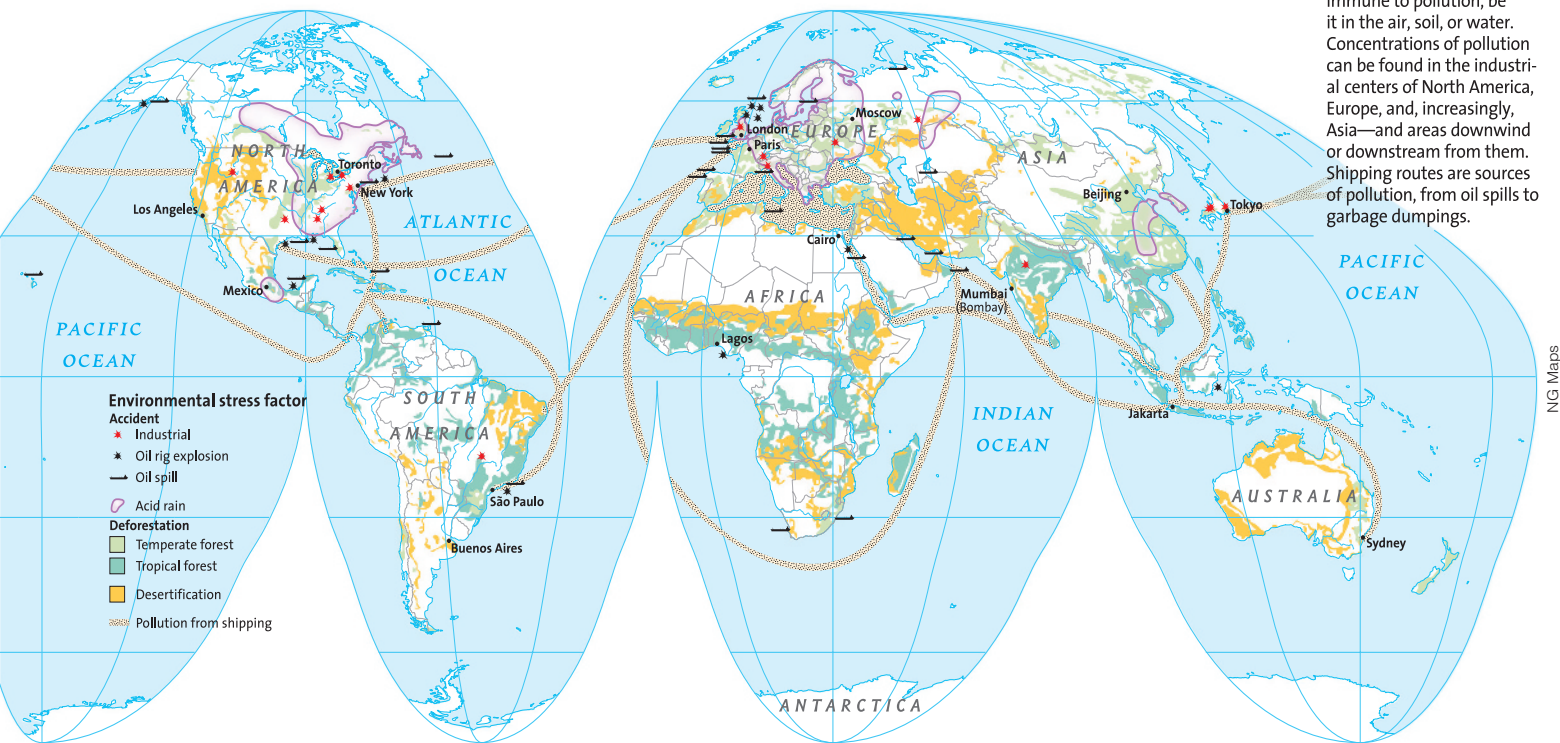
ACCIDENTAL DROWNINGS

Entanglement in fishing gear is one of the greatest threats to marine mammals.

A FAREWELL TO FROGS?

Worldwide, almost half of the 5,700 named amphibian species are in decline.

With the growth of scientific record keeping, observation, modeling, and analysis, our understanding of Earth's environment is improving. Yet even as we deepen our insight into environmental processes, we are changing what we are studying. At no other time in history have humans altered their environment with such speed and force. Nothing occurs in isolation, and stress in one area has impacts elsewhere. Our agricultural and fishing practices, industrial processes, extraction of resources, and transportation methods are leading to extinctions, destroying habitats, devastating fish stocks, disturbing the soil, and polluting the oceans and the air. As a result, biodiversity is declining, global temperatures are rising, polar ice is shrinking, and the ozone layer continues to thin.

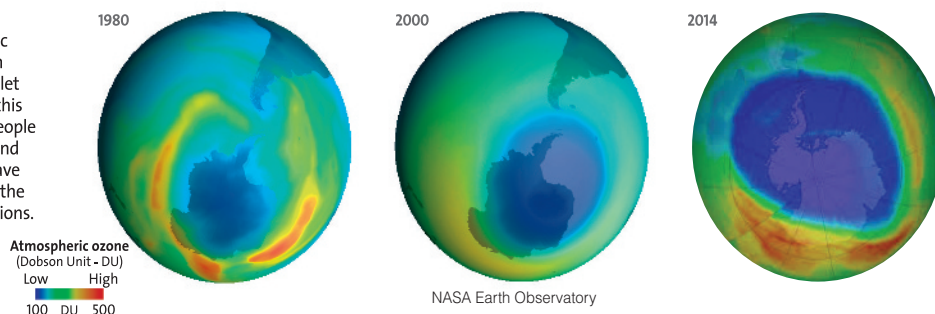


▼ POLLUTION
No corner of the earth is immune to pollution, be it in the air, soil, or water. Concentrations of pollution can be found in the industrial centers of North America, Europe, and, increasingly, Asia—and areas downwind or downstream from them. Shipping routes are sources of pollution, from oil spills to garbage dumpings.

► OZONE DEPLETION

First noted in the mid-1980s, the springtime “ozone hole” over the Antarctic continues to grow. With sustained efforts to restrict chlorofluorocarbons (CFCs) and other ozone-depleting chemicals, scientists have begun to see what they hope is a leveling off in the rate of

depletion. Stratospheric ozone shields the Earth from the sun's ultraviolet radiation. Thinning of this protective layer puts people at risk for skin cancer and cataracts. It can also have devastating effects on the Earth's biological functions.



NASA Earth Observatory

Environmental Science

LEARNING OBJECTIVES

1. **Define** *environmental science*.
2. **Outline** the steps of the scientific method.

Environmental science is an interdisciplinary field that combines information from many disciplines, such as biology, geography, chemistry, geology, physics, economics, sociology (particularly *demography*, the study of populations), cultural anthropology, natural resource management, agriculture, engineering, law, politics, and ethics.

Ecology, the discipline of biology that studies the interrelationships between organisms and their environment, is a basic tool of environmental science. **Atmospheric science** is a branch of environmental science that includes the study of weather and climate, greenhouse gases, and other airborne pollutants (**Figure 1.8**). **Environmental**

environmental science The interdisciplinary study of humanity's relationship with other organisms and the physical environment.

chemistry examines chemicals in the environment, including air, soil, and water pollution. **Geosciences**—for example, environmental geology and physical geography—study a wide range of environmental topics, such as soil erosion, groundwater use, ocean

pollution, and climate. Scientists in these subdisciplines not only evaluate environmental quality but also develop ways to restore damaged environments.

The Goals of Environmental Science

Environmental scientists try to establish general principles about how the natural world functions. They use these principles to develop viable solutions to environmental problems—solutions that are based as much as possible on scientific knowledge.

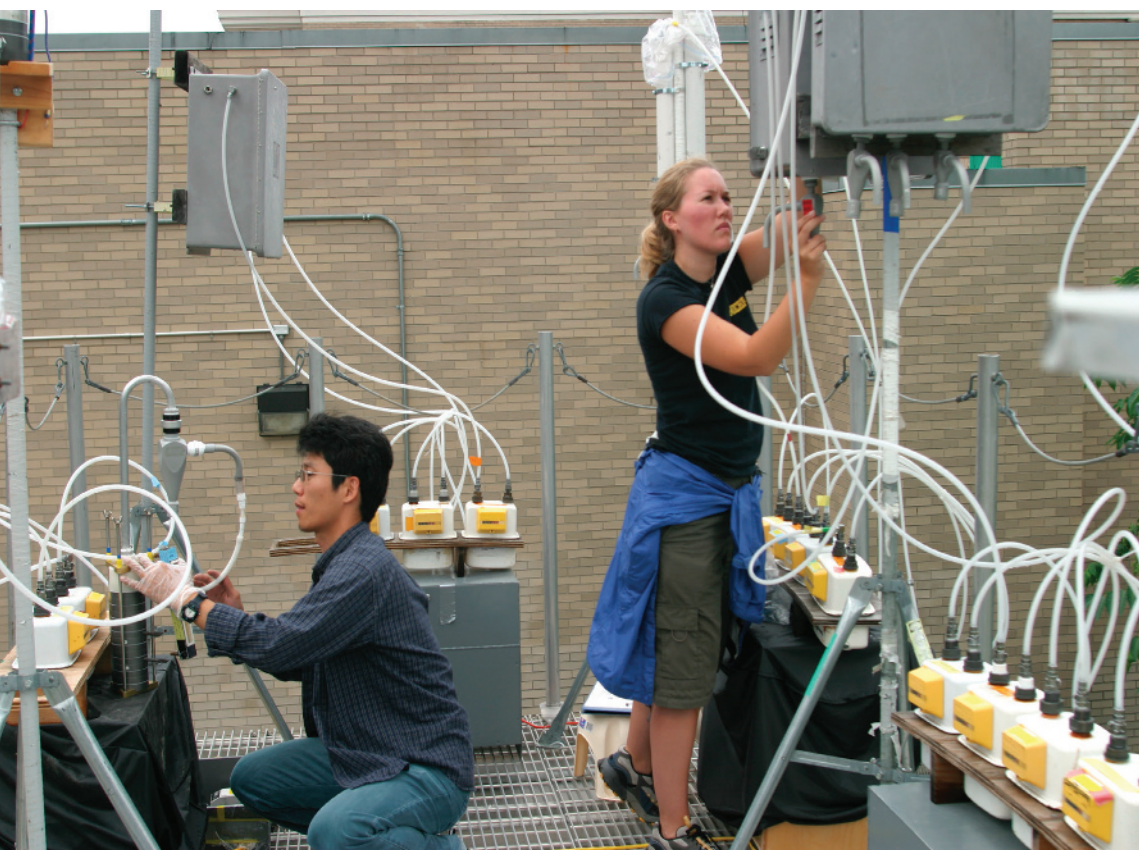
Environmental problems are generally complex, however, and scientific understanding of them is often less complete than we would like. Environmental scientists are often called on to reach scientific consensus before the data are complete. As a result, they often cannot give precise answers and so instead make recommendations based on what they think is most likely to occur.

Many of the environmental problems considered in this book require urgent attention. Yet environmental science is not simply a “doom and gloom” listing of problems, coupled with predictions of a bleak future. To the contrary, the focus of environmental science, and our focus as individuals and as world citizens, is

Environmental researchers

• Figure 1.8

These scientists are testing air quality in Detroit, Michigan, as part of a study to better understand the relationship between air pollution and asthma.



on identifying, understanding, and solving problems that we as a society have generated. Over the past half century, science-informed environmental policies have profoundly improved human wellbeing worldwide. Even so, we can continue to reduce our impact on the environment in many ways.

Science as a Process

The key to successfully solving any environmental problem is rigorous scientific evaluation. In order to use science to inform decisions, we must understand what science is, as well as what it is not. Most people think of **science** as a body of knowledge—a collection of facts about the natural world. However, science is also a dynamic *process*, a systematic way to investigate the natural world. Science seeks to reduce the apparent complexity of our world to general principles, which are

then used to make predictions, solve problems, or provide new insights.

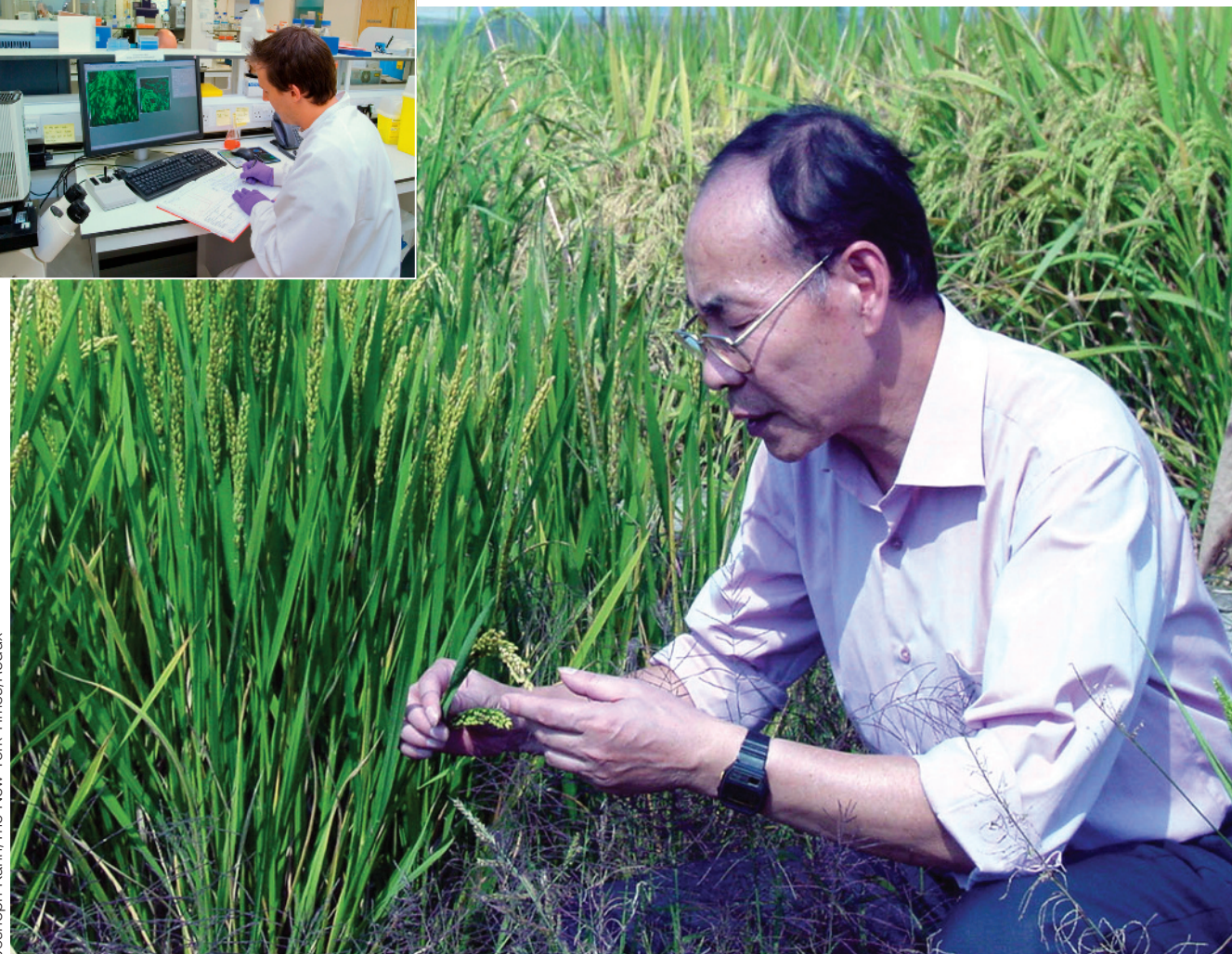
Scientists collect objective **data** (singular, *datum*), the information with which science works. Data are collected through observation and experimentation and then analyzed or interpreted (**Figure 1.9**). Scientific conclusions are inferred from the available data and are not based on faith, emotion, or intuition. Scientists publish their findings in scientific journals, and other scientists examine and critique their work. A requirement of science is repeatability—that is, observations and experiments must produce consistent data when they are repeated. Scrutiny by other scientists reveals any inconsistencies in results or interpretation. The scientific community discusses errors openly, and does additional studies designed to eliminate them.

Science is an ongoing enterprise, and scientific concepts must be reevaluated in light of newly discovered data.

Data collection • Figure 1.9



A researcher observes genetically modified rice plants. Photographed at Cornell University, New York. (Inset) A scientist records his data on a computer in the laboratory.



Thus, scientists never claim to know the final answer about anything because scientific understanding changes.

This is not to say, however, that all ideas are equally valid. Rather, the scientific processes evaluate and then reject ideas that are inconsistent with theory and data. Thus, despite many uncertainties, science provides usable insights on many aspects of environmental change and management. While science tells us what *is* and what *can be*, it cannot tell us what *should be*. Questions about what should be are in the realm of religion, ethics, policy, and philosophy. Once we have used these approaches to decide on our priorities and preferences, science is the most useful tool available to help us achieve them. Science aims to discover and better understand the general principles that govern the operation of the natural world.

The Scientific Method The established processes that scientists use to answer questions or solve problems are collectively called the **scientific method**. Although there are many variations of the scientific method, it basically involves five steps:

scientific method

The way a scientist approaches a problem, by formulating a hypothesis and then testing it.

1. Recognize a question or an unexplained phenomenon in the natural world.
2. Develop a *hypothesis*, or the expected answer to the question.
3. Design and perform an experiment to test the hypothesis.
4. Analyze and interpret the data to reach a conclusion.
5. Share new knowledge with the scientific community.

Although the scientific method is often portrayed as a linear sequence of events, science is rarely as straightforward or tidy as the scientific method implies (**Figure 1.10**). Good science involves creativity, not only in recognizing questions and developing hypotheses but also in designing experiments. Because scientists try to expand our current knowledge, their work is in the realm of the unknown. Many creative ideas end up as dead ends, and there are often temporary setbacks or reversals of direction as scientific knowledge progresses. Scientific knowledge often expands haphazardly, with the “big picture” emerging slowly from confusing and sometimes contradictory details.

Scientific discoveries are often incorrectly portrayed in the media as “new facts” that have just come to light. At a later time, additional “new facts” that question the validity of the original study are reported. If you were to read the scientific papers on which such media reports are based, however, you would find that all the scientists

involved probably made very tentative conclusions based on their data. Science progresses from uncertainty to less uncertainty, not from certainty to greater certainty. Thus, science is self-correcting over time, despite the fact that it never “proves” anything.

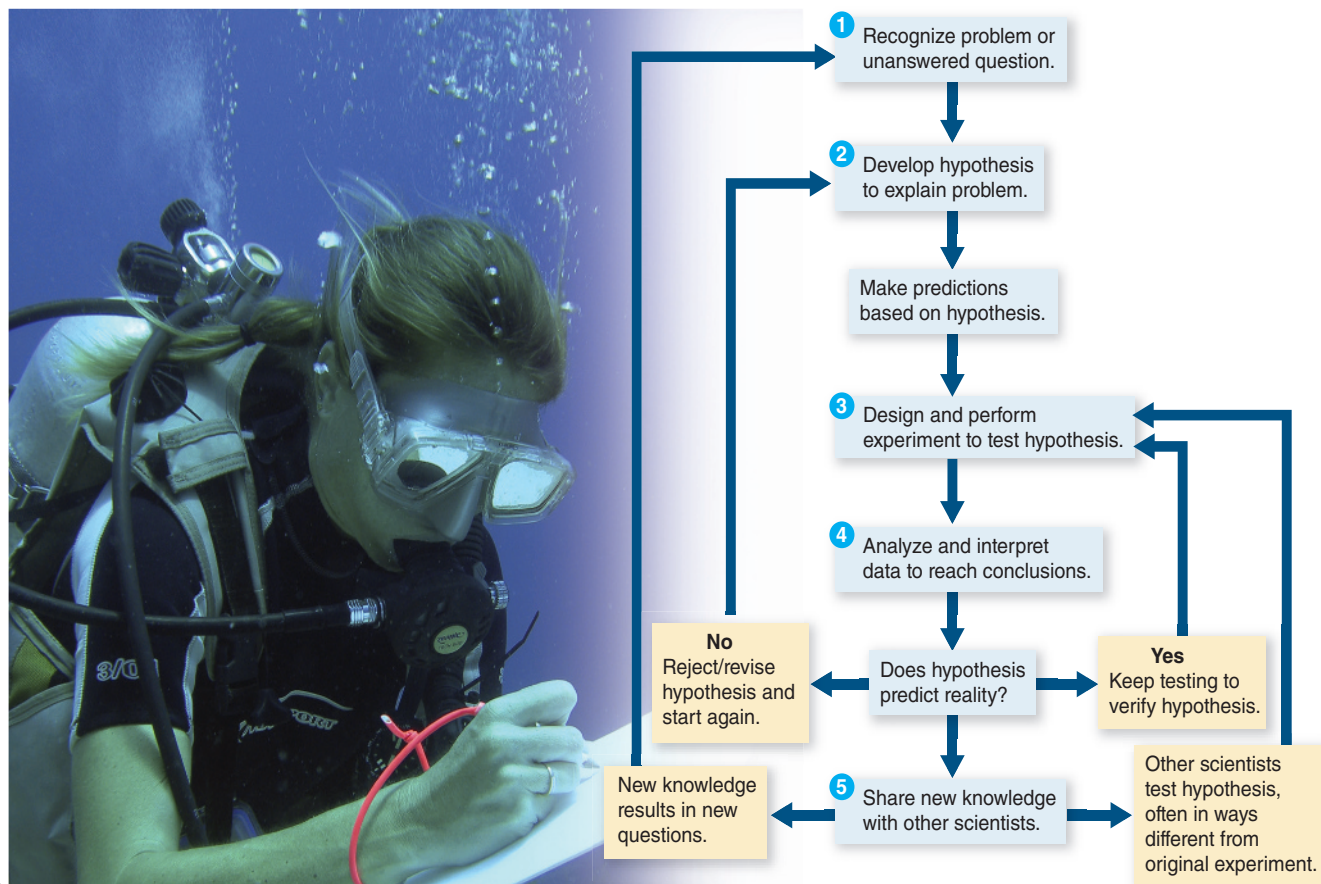
The Importance of Prediction Scientists formulate **hypotheses** (plural of hypothesis) based on what they think to be true based on prior scientific work. A hypothesis is a statement of that expectation. A hypothesis is useful if it can be falsified (shown to be wrong) and tested. A hypothesis is a prediction that can be subjected to experimentation. When an experiment refutes a prediction, scientists must carefully recheck the entire experiment. If the prediction is still refuted, then the hypothesis must be rejected. The more verifiable predictions a hypothesis makes, the more valid that hypothesis is.

Each of the many factors that influence a process is called a **variable**. To evaluate alternative hypotheses about a specific variable, it is necessary to hold all other variables constant so that they are not misleading or confusing. To test a hypothesis about a variable, we carry out two forms of the experiment in parallel. In the **experimental group**, the chosen variable is altered in a known way. In the **control group**, that variable isn’t altered. In all other respects, the experimental group and the control group are the same. We then ask, “What is the difference, if any, between the outcomes for the two groups?” Any difference must be due to the influence of the variable we changed because all other variables remained the same. Much of the challenge of science lies in designing control groups and in successfully isolating a single variable from all other variables.

Theories A **theory** is an integrated explanation of numerous hypotheses, each of which is supported by a large body of observations and experiments. A theory condenses and simplifies many data that previously appeared to be unrelated. Because a theory demonstrates the relationships among different data, it simplifies and clarifies our understanding of the natural world. A good theory grows as additional information becomes known. It predicts new data and suggests new relationships among a range of natural phenomena.

Theories are the solid ground of science, the explanations of which we are most sure. This definition contrasts sharply with the general public’s use of the word *theory*, which implies lack of knowledge or a guess. In this book, the word *theory* is always used in its scientific sense, to refer to a broadly conceived, logically coherent, and well-supported explanation.

The scientific method • Figure 1.10

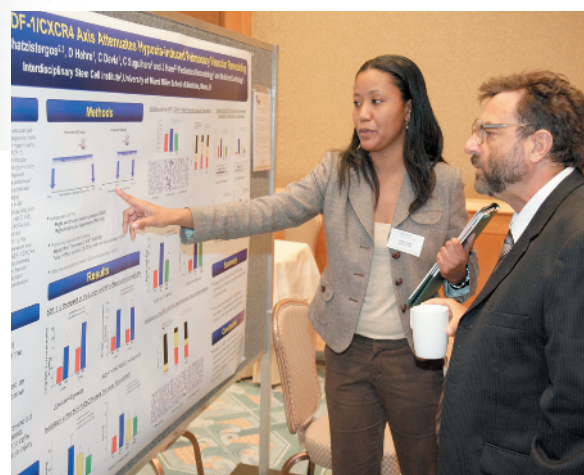


These five steps provide the framework for all scientific investigations.

Nicole Duplaix/NG Image Collection

3 A field scientist makes observations critical to understanding damage to coral reefs from global climate change. Photographed at Turneffe Atoll, Belize.

5 Many scientists present their research during poster sessions at scientific meetings. This allows their work to be critically assessed by others in the scientific community.



Jeff Greenberg/Alamy Limited

Think Critically What is the relationship between a hypothesis and an experiment?

Unfortunately, many questions that are most important to environmental scientists cannot be formulated as testable hypotheses. For example, we cannot design an experiment to test the hypothesis that if we double the carbon dioxide concentration of the atmosphere, global average temperatures will increase. Consequently, much of environmental science requires that we apply our best understanding of theory and data to arrive at conclusions about what we expect will happen.

Despite the fact that theories are generally accepted, there is no absolute truth in science, only varying degrees of uncertainty. Science is continually evolving as new evidence comes to light, and therefore its conclusions are always provisional or uncertain. It is always possible that the results of a future experiment will contradict a prevailing theory and show at least one aspect of it to be false.

Uncertainty, however, does not mean that scientific conclusions are invalid. For example, overwhelming evidence links cigarette smoking and incidence of lung cancer. We can't state with absolute certainty which smokers will be diagnosed with lung cancer, but this

uncertainty does not mean that there is no correlation between smoking and lung cancer. On the basis of the available evidence, we say that people who smoke have an increased risk of developing lung cancer.

In conclusion, the aim of science is to increase human comprehension by explaining the processes and events of nature. Scientists work under the assumption that all phenomena in the natural world have natural causes, and they formulate theories to explain these phenomena. The process of science as a human endeavor has shaped the world we live in and transformed our views of the universe and how it works.

CONCEPT CHECK



1. **What** is environmental science? What are some of the disciplines involved in environmental science?
2. **What** are the five steps of the scientific method? Why is each important?

How We Handle Environmental Problems

LEARNING OBJECTIVE

1. **List** and briefly describe the five stages of solving environmental problems.

Before examining the environmental problems discussed in the remaining chapters of this book, let's consider the elements that contribute to solving those problems. How, for example, can we handle water pollution in a river (**Figure 1.11**)? At what point are conclusions regarded as certain enough to warrant action? Who makes the decisions, and what are the trade-offs? Viewed

Monitoring water pollution • Figure 1.11

This pollution control officer is measuring the oxygen level in the Severn River near Shrewsbury, England. When dissolved oxygen levels are high, pollution levels (for example from sewage or fertilizer) are low.

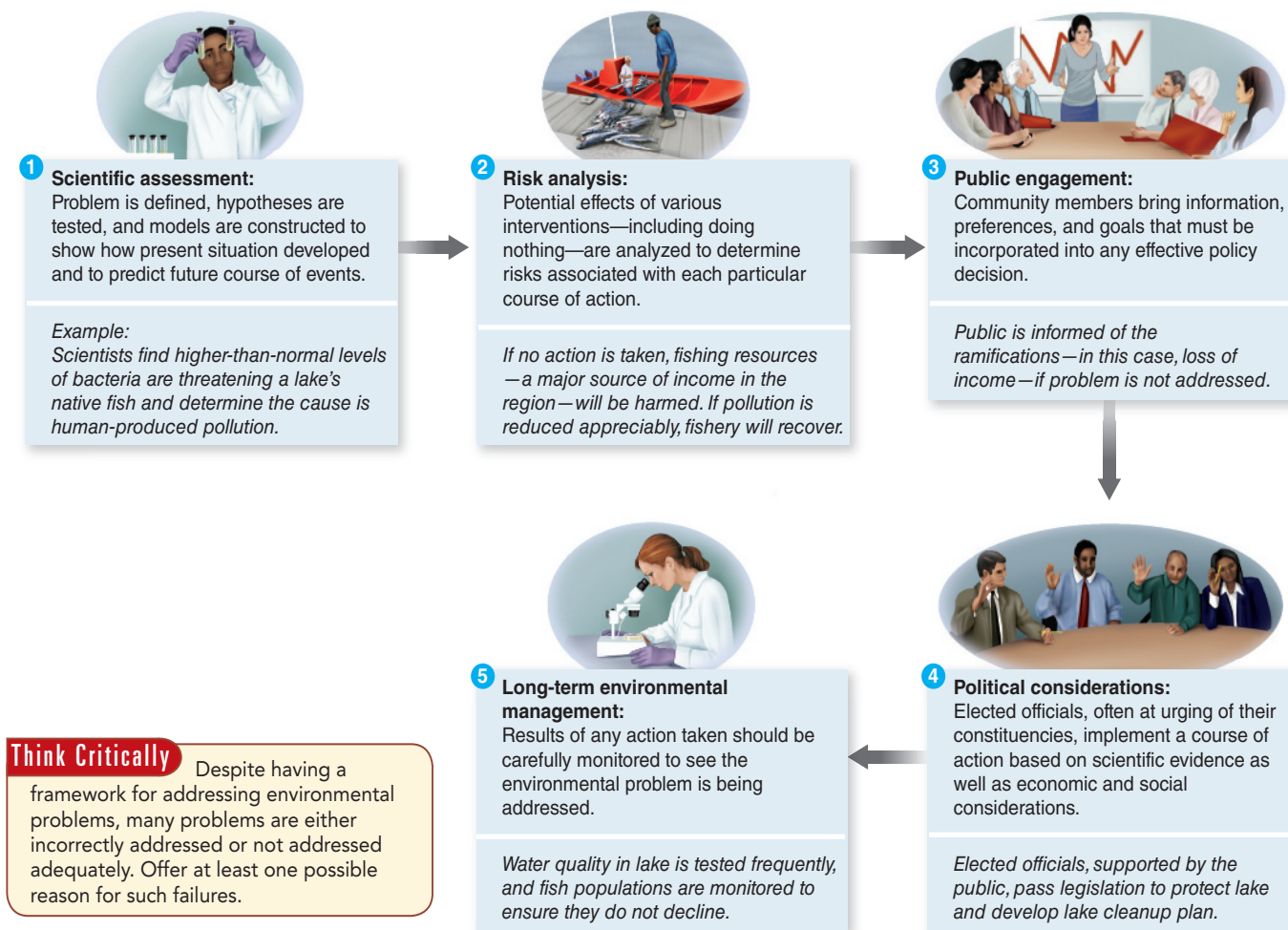


Ben Osborne/Stone/Getty Images

Addressing environmental problems • Figure 1.12



These five steps provide a framework for addressing environmental problems.



Think Critically Despite having a framework for addressing environmental problems, many problems are either incorrectly addressed or not addressed adequately. Offer at least one possible reason for such failures.

simply, there are five stages in addressing an environmental problem (Figure 1.12):

1. Scientific assessment
2. Risk analysis
3. Public engagement
4. Political considerations
5. Long-term environmental management

These five stages represent an ideal approach to systematically addressing environmental problems. In real life, seeking solutions to environmental problems is rarely so neat and tidy, particularly when the problem

is exceedingly complex, is of regional or global scale, or has high costs and unclear benefits for the money invested (see Case Study 1.1). Quite often, the public becomes aware of a problem, which triggers discussion of remediation before the problem is clearly identified and scientifically assessed (see EnviroDiscovery 1.2).

CONCEPT CHECK



1. **What** are the five steps used to solve an environmental problem?
2. **When** might public engagement come before scientific assessment?

EnviroDiscovery 1.2

Getting Past NIMBY

Our highly industrialized, high-consumption economy produces substantial amounts of waste, many of them dangerous and long-lived. Keeping these wastes where they are generated can create significant threats to human and environmental health and safety. Consequently, waste producers constantly seek locations for permanent disposal. Unfortunately, any disposal site exposes some people to threats from either the facility or associated transportation.

When people hear that a power plant, an incinerator, or a hazardous waste disposal site may be situated nearby, residents often react negatively. Their objections are often referred to as the NIMBY (“not in my back yard”) response. In most situations, the people who would be exposed to the new threat are not the people who stand to gain from them. In other cases, people who are labeled as NIMBYs object to being excluded from the decision-making process. Developers and public planners often fail to engage people living in low-income urban areas, older suburban areas, or rural areas to help make decisions that affect their neighborhoods.

Exacerbating the NIMBY response is the failure by companies and government to develop processes for listening and responding to public concerns. The experts they bring in are seen as part of the problem and are distrusted by local residents. When experts are not trusted, people don’t believe their analyses, no matter how scientifically valid. Experts, who typically do not have training in effective communication, interpret this distrust as ignorance or emotion. Resentment and conflict follow.

Consider the disposal of radioactive waste from nuclear power plants. There is broad agreement that the best long-term solution is to safely isolate radioactive waste, preferably deep underground, for thousands of years. However, rather than explore a range of possible disposal sites, the U.S. government, backed by the nuclear energy industry, committed in 1982 to explore only a single disposal site, Yucca Mountain in Nevada. It then spent the next three decades studying only that site. As Nevada became more politically powerful, its residents objected to the process, which was often interpreted as an “antiscientific” NIMBY attitude. Only recently (in 2010) did a new process begin, one that incorporates broad perspectives and stakeholders in a national conversation.

Most people agree that our generation has the responsibility to dispose of wastes we generate. Failure to find appropriate long-term solutions can result in more dangerous short-term solutions, or illegal and unsafe dumping. For existing wastes and technologies, then, planners should use approaches that look for socially, economically, and environmentally sound solutions—that is, for sustainable solutions.

The constant recurrence of the NIMBY phenomenon suggests that we should also consider a more sophisticated, systems-based approach. Life-cycle assessment takes a systems perspective on technological threats. Rather than ask “how do we safely dispose of wastes,” life-cycle assessment considers how to change processes and materials in a way that minimizes waste production. In many cases, life-cycle assessment leads to innovations that save money, require less energy, and produce fewer wastes.

Not in my backyard

Steam rises from two of the cooling towers of a nuclear power plant. All nuclear power plants in the United States currently store highly radioactive spent fuel on site because there is no approved place to safely dispose of it.



CASE STUDY 1.1



The New Orleans Disaster

Hurricane Katrina, which hit the north-central Gulf Coast in August 2005, was one of the most devastating storms in U.S. history. It produced a storm surge that caused severe damage to New Orleans as well as to other coastal cities and towns in the region. The high waters caused levees and canals to fail, flooding 80 percent of New Orleans and many nearby neighborhoods.

Most people are aware of the catastrophic loss of life and property caused by Katrina. Here we focus on how humans altered the geography and geology of the New Orleans area in ways that exacerbated the storm damage.

Over the years, engineers constructed a system of canals to aid navigation and a system of levees to control flooding because the city is at or below sea level. The canals allowed salt water to intrude and kill the freshwater marsh vegetation. The levees prevented the deposition of sediments that remain behind after floodwaters subside. (The sediments are now deposited in the Gulf of Mexico.) Under natural conditions, these sediments replenish and maintain the delta, building up coastal wetlands.

As the city has grown, new development has taken place on wetlands—bayous, waterways, and marshes—that were drained and filled in. Before their destruction, these coastal wetlands provided some protection against flooding from storm surges. We are not implying that had Louisiana's wetlands been intact, New Orleans would not have suffered any damage from a hurricane of Katrina's magnitude. However, had these wetlands been largely unaltered, they would have moderated the storm's damage by absorbing much of the water from the storm surge.

Another reason that Katrina devastated New Orleans is that the city has been subsiding (sinking) for many years, primarily because New Orleans is built on unconsolidated sediment (no bedrock underneath). Many wetlands scientists also attribute this subsidence to the extraction of the area's rich supply of underground natural resources—groundwater, oil, and natural gas. As these resources are removed, the land compacts, lowering the city. New Orleans and nearby coastal areas are subsiding an average of 6 mm each year (see image). At the same time, the sea level has been rising an average of 1 mm to 2.5 mm per year due to human-induced changes in climate.

This satellite image shows flooding in New Orleans following Hurricane Katrina. Along the left (west) side is a levee from Lake Ponchartrain (top) that failed so that water inundated the New Orleans area east of the levee. Areas on the far left top remained dry. Part of the Mississippi River is shown at lower center.

UPI Photo/IKONOS/NewsCom



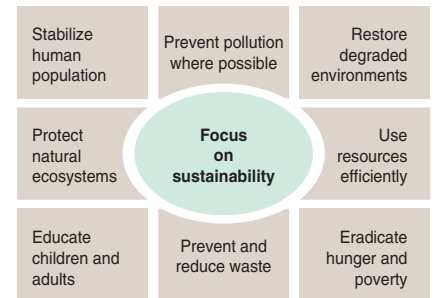
Summary



1 Human Impacts on the Environment 4

1. **Highly developed countries** are countries that have complex industrialized bases, low rates of population growth, and high per person incomes. **Moderately developed countries** are developing countries that have medium levels of industrialization and average per person incomes lower than those of highly developed countries. **Less developed countries (LDCs)** are developing countries with low levels of industrialization, very high rates of population growth, very high infant mortality rates, and very low per person incomes (relative to highly developed countries). **Poverty**, which is common in LDCs, is a condition in which people are unable to meet their basic needs for food, clothing, shelter, education, or health.
2. The increasing global population is placing stresses on the environment, as humans consume ever-increasing quantities of food and water, use more energy and raw materials, and produce enormous amounts of waste and pollution. **Nonrenewable resources** are natural resources that are present in limited supplies and are depleted as they are used. **Renewable resources** are resources that natural processes replace and that therefore can be used forever, provided that they are not exploited in the short term.
3. The forces that drive environmental impact can be modeled by the IPAT model, $I = P \times A \times T$. Environmental impact (I) has three factors: the number of people (P); the affluence per person (A), which is a measure of the consumption, or amount of resources used per person; and the environmental effect of the technologies used to obtain and consume those resources (T).

2. Human behaviors that threaten environmental sustainability include overuse of renewable and nonrenewable resources, pollution, and population growth.



3 Environmental Science 16

1. **Environmental science** is the interdisciplinary study of humanity's relationship with other organisms and the nonliving physical environment. Environmental science encompasses many problems involving human numbers, Earth's natural resources, and environmental pollution. While science always includes some degree of uncertainty, it nevertheless provides useful information for many environment-related decisions.
2. The **scientific method** is the way a scientist approaches a problem, by formulating a **hypothesis** and then testing it by means of an experiment. (1) A scientist recognizes and states the problem or unanswered question. (2) The scientist develops a hypothesis, or an educated guess, to explain the problem. (3) An experiment is designed and performed to test the hypothesis. (4) **Data**, the results obtained from the experiment, are analyzed and interpreted to reach a conclusion. (5) The conclusion is shared with the scientific community.

2 Sustainability and the Environment 12

1. **Sustainability** is the ability to meet humanity's current needs without compromising the ability of future generations to meet their needs. Sustainability is achieved when the environment can function indefinitely without going into a decline from the stresses that human society imposes on natural systems. Taking a sustainability perspective requires that we think simultaneously about economic, social, and environmental well-being.

4 How We Handle Environmental Problems 20

1. Addressing environmental problems ideally requires five stages. (1) Scientific assessment involves identifying a potential environmental problem and collecting data to construct a model. (2) Risk analysis evaluates the potential effects of intervention. (3) Public engagement occurs when the results of scientific assessment and risk analysis are placed in the public arena. (4) In political considerations, elected or appointed officials implement a particular risk-management strategy. (5) Long-term environmental management monitors the effects of the action taken.

Key Terms

- environmental science 16
- highly developed countries 4
- less developed countries 6
- moderately developed countries 6
- nonrenewable resources 7
- poverty 4
- renewable resources 7
- scientific method 18
- sustainability 12

What is happening in this picture?

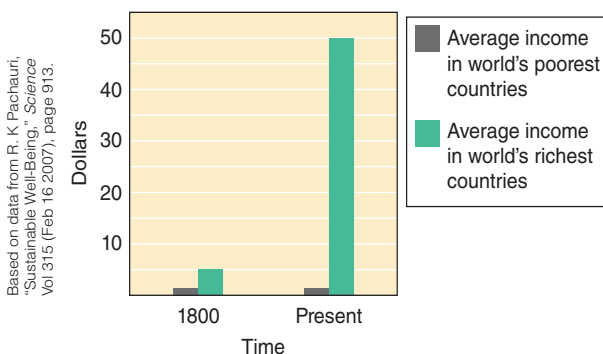
- What are these people protesting?
- How is this opposition an example of NIMBY?
- What sorts of political processes and scientific information might make it easier to find a long-term solution to nuclear waste management?



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Critical and Creative Thinking Questions

1. Provide arguments for and against the following statement: "Population growth in developing countries is of much more concern than is population growth in highly developed countries."
2. Describe multidimensional poverty.
3. Explain why a country with the world's highest overall consumption may not have the largest population.
4. Explain how population, affluence, and technology interact in complex ways.
5. Do you think our current worldwide population growth and economic growth are sustainable? Why or why not?
6. Give at least two examples of things that you can do as an individual to promote sustainability.
7. How does the field of environmental science involve science? economics? politics?
8. Your throat feels scratchy, and you think you're coming down with a cold. You take a couple of vitamin C pills and feel better. You conclude that vitamin C helps prevent colds. Is your conclusion valid from a scientific standpoint? Why or why not?
9. People want scientists to give them precise, definitive answers to environmental problems. Explain why this is not possible, and why science is, nonetheless, useful for managing environmental problems.
10. Examine the graph, which shows an estimate of the discrepancy between the wealth of the world's poorest countries and that of the richest countries.
- a. How has the distribution of wealth changed from the 1800s to the present? How would you explain this difference?
- b. Based on the trend evident in this graph, predict what the graph might look like in 100 years.
- c. Some economists think that our current path of economic growth is unsustainable. Do the data in this graph support or refute this idea? Explain your answer.



Sustainable Citizen Question

11. Making effective personal and professional decisions requires access to appropriate, high-quality information. In this chapter, we have described how the scientific process can inform decisions. Where would you go for information to make decisions about the environment? How would you rank the following as trusted sources? Which of these do you rely on?
 - Friends and family
 - Social media (Twitter, Facebook, Instagram)
 - News media (websites, newspapers, magazines, television, radio)
 - Scientific journals (see image)
 - Textbooks
 - Political leaders

Rural Nevada and Climate Change: Vulnerability, Beliefs, and Risk Perception

Ahmad Saleh Safi,^{1,*} William James Smith, Jr.,² and Zhongwei Liu³

In this article, we present the results of a study investigating the influence of vulnerability to climate change as a function of physical vulnerability, sensitivity, and adaptive capacity on climate change risk perception. In 2008/2009, we surveyed Nevada ranchers and farmers to assess their climate change-related beliefs, and risk perceptions, political orientations, and socioeconomic characteristics. Ranchers' and farmers' sensitivity to climate change was measured through estimating the proportion of their household income originating from highly scarce water-dependent agriculture to the total income. Adaptive capacity was measured as a combination of the Social Status Index and the Poverty Index. Utilizing water availability and use, and population distribution GIS databases, we assessed water resource vulnerability in Nevada by zip code as an indicator of physical vulnerability to climate change. We performed correlation tests and multiple regression analyses to examine the impact of vulnerability and its three distinct components on risk perception. We find that vulnerability is not a significant determinant of risk perception. Physical vulnerability alone also does not impact risk perception. Both sensitivity and adaptive capacity increase risk perception. While age is not a significant determinant of it, gender plays an important role in shaping risk perception. Yet, general beliefs such as political orientations and climate change-specific beliefs such as belief in the anthropogenic cause of climate change were found to be significant determinants of risk perception.

A.S. Safi, W.J. Smith, Jr., and Z. Liu, "Rural Nevada and Climate Change: Vulnerability, Beliefs, and Risk Perception," *Risk Analysis*, Volume 32, Issue 6, June, 2012: 1041–1059. This material is reproduced with permissions of John Wiley & Sons, Inc.



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