6.7 Ecological Problems

Learning Outcomes

1. Compare the age structure of a developed country and a developing country.
2. Explain the relationship between overpopulation and depletion of world resources.
3. Analyze the threats to Earth's biodiversity.

Barry Commoner (1917–2012) was a scientist, environmental and social activist, author, and presidential candidate (1980) who studied and taught at Washington University in St. Louis, Missouri. He is credited by many ecologists with being the father of the environmental movement, but his vision was wider than biology. He recognized that Earth's problems—ecological degradation, social injustice, and economic and national security—are all interconnected. He was one of the first to say that no permanent environmental solutions exist without social change. His four "laws of ecology" have become the cornerstones of the environmental movement. (1) Everything in the entire Earth ecosystem is interconnected. Damaging one part of an ecosystem has wide-ranging effects on the whole. (2) Everything must go somewhere. There is no place to put waste where it will not resurface in the future. (3) Nature knows best. Human-induced changes to ecosystems, what we think of as "improvements," are always detrimental to the ecosystems. (4) There is no "free lunch." Every environmental change has a consequence. The consequence can sometimes be delayed, but it cannot be avoided for long.

Now that you have studied some general ecological principles, it should be easier to understand why Commoner's rules are true. In this last section of **chapter 6**, we link basic ecological principles to conservation issues that we face.

Human Population Growth

An expanding human population is the root of virtually all environmental problems. Human populations, like those of other animals, tend to grow exponentially. The earth, like any ecosystem on it, has a carrying capacity and a limited supply of resources. When human populations achieve that carrying capacity, populations should stabilize. If they do not stabilize in a fashion that limits human misery, then war, famine, and/or disease are sure to take care of the problem.

What is the earth's carrying capacity? The answer is not simple. In part, it depends on the desired standard of living and on whether or not resources are distributed equally among all populations. The earth's population currently stands at 7.6 billion people. Virtually all environmentalists agree that the number is too high.

Efforts are being made to curb population growth in many countries, and these efforts have met with some success. Looking at the age characteristics of world populations helps explain why control measures are needed. The **age structure** of a population shows the proportion of a population in prereproductive, reproductive, and postreproductive classes. Age structure is often represented by an age pyramid. **Figure 6.13** shows an age pyramid for a developed country and for a developing country. In developing countries like Kenya, the age pyramid has a broad base, indicating high birthrates. As in many natural populations, high infant mortality offsets these high birthrates. However, what happens when developing countries begin accumulating technologies that reduce prereproductive mortality and prolong the lives of the elderly? Unless reproductive practices change, a population explosion occurs and problems associated with housing, employment, education, food production, and health care are compounded.

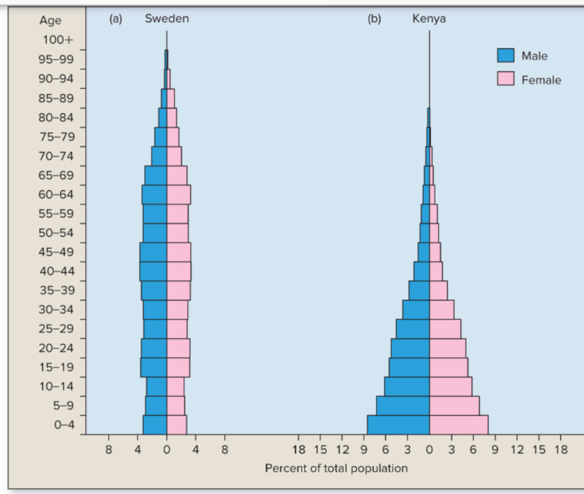

FIGURE 6.13 **Human Age Pyramids** (*a*) In developed countries, the age structure is parallel-sided because mortality in all age classes is relatively low. In this example, the slight widening of the pyramid in the 45 to 65 age range is because of the "baby boom" that occurred between 1945 and 1965. (*b*) In developing countries, a greater proportion of the population is in the prereproductive age classes. High mortality compensates for high birthrates, and the pyramid is triangular. As technologies reduce infant mortality and prolong the life span of the elderly, populations increase rapidly.

The United Nations Population Division projects that the current world population of 7.6 billion will increase to 9.7 billion by 2050 and 10.9 billion by 2100. Average human fertility across the globe ranges between 4.5 children per woman (usually in the least developed countries) and 1.6 children per woman (usually in the more developed countries). Even in countries with the lowest fertility, populations are growing because of increased longevity and immigration from other parts of the world. The increase in older age classes is already straining the economics of elder care.

Earth's Resources and Global Inequality

Aldo Leopold (1887–1948), author of *A Sand County Almanac: And Sketches Here and There*, once said:

> A thing is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends otherwise.

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It is right that we preserve Earth's resources for the sake of the earth. It is also right because we humans depend on those resources for our lives. Unfortunately there is a tremendous global inequality in the use of Earth's resources that has led to environmental degradation across the globe and human suffering in many regions of the world. It is estimated that the earth has approximately 1.9 hectares of productive resources (crop, grazing, forest, and fishing) per person. Supporting the lifestyles of people in the United States requires about 9.5 hectares of productive resources. (Western Europeans require about half of that area.) This amount is in contrast to the use of less than 0.5 hectares by the average Mozambican. To put it another way, 12% of the world's population lives in North American and western Europe, and these populations account for 60% of the world's consumption. In contrast, 33% of the world's population lives in southern Asia and sub-Saharan Africa and account for 3.2% of the world's consumption. The results of unbridled consumption and development have had devastating consequences for Earth's natural systems.

Biodiversity

The variety of living organisms in an ecosystem is called **biodiversity**. No one knows the number of species in the world. About 1.6 million species have been described, but taxonomists estimate that there may be up to 10 million total. A rich biodiversity is of inestimable value in natural systems. Every life-form, no matter how small, plays very important roles in Earth's ecosystems. Greater diversity of species creates natural sustainability for all our ecosystems. Healthy ecosystems are better able to withstand and recover from disturbances. Diverse ecosystems protect our water and soil resources; promote nutrient cycling and climate stability; and provide biological resources, including food, medicines, wood products, and novel genomes that benefit ecosystem and human populations. All of these functions require large, healthy populations. Large populations provide the genetic diversity required for surviving environmental changes. E.O. Wilson (ant biologist, naturalist, and father of the biodiversity movement) emphasized the importance of these ecosystem services when he said:

> Look closely at nature. Every species is a masterpiece, exquisitely adapted to the particular environment in which it has survived. Who are we to destroy or even diminish biodiversity?

The biodiversity of all natural areas of the world is threatened. In spite of greater awareness of environmental problems, the rate of biodiversity loss has not been reduced. The International Union for Conservation of Nature (IUCN) surveyed nearly 48,000 species and concluded that 46% resided in one of their extinction risk categories, ranging from extinct to a near threatened status. Biodiversity loss continues for five reasons discussed in the following sections.

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Habitat Loss

Habitat loss and degradation displaces thousands of native plants and animals. Some of the most important threatened natural areas include tropical rain forests, coastal wetlands, and coral reefs (*see page 153*). Of these, tropical rain forests have probably received the most attention. Tropical rain forests cover only 7% of the earth's land surface, but they contain more than 50% of the world's species. They provide a wealth of economic and ecological services—providing novel medicines and foods, climate control through absorption of CO_2 from the atmosphere, and protection of delicate soil and water resources. Tropical rain forests are being destroyed rapidly, mostly for agricultural production. About 32 million hectares (an area the size of the state of Louisiana) are being cleared each year (*see* ***figure 1.6a***, **b**). Loss of forest vegetation is accompanied by the loss of thousands of forest animals and forest soils. At current rates of destruction, most tropical rain forests will disappear this century.

Climate Change and Ocean Acidification

We have seen that cycling of material is a fundamental property of ecosystems. There are consequences to altering portions of a biogeochemical cycle, and understanding climate change requires understanding the carbon cycle (*see* ***figure 6.12***). There is a clear and overwhelming consensus among climate scientists—climate change is real, and climate-warming trends of the past decades are due to human activities. Climate change is a by-product of our dependence on fossil fuels. China and the United States are responsible for over 40% of the greenhouse gas emissions (principally CO_2, *see* ***table 1.4***). We have disrupted the carbon cycle by increasing the rate of CO_2 accumulation in the atmosphere from burning fossil fuels and by decreasing the rate of carbon fixation into organic matter through deforestation. Earth's temperature is determined by the relationship between the absorption of heat from the sun and radiation of heat from the earth back into space. Non-condensing greenhouse gases (principally CO_2) act as a thermostat to regulate the amount of water vapor and cloud cover in the atmosphere. Together, these gases create an insulating blanket that reduces the radiation of heat into space and cause global temperatures to increase. According to the Fourth Assessment Report by the United Nations Intergovernmental Panel on Climate Change (2007), global surface temperatures increased by 0.74°C during the last century, most of the change coming since 1950. A further increase in global temperature of 1.4–6.4°C is projected for the twenty-first century. Climate change promotes the melting of glaciers, loss of polar ice sheets, disruption of freshwater supplies, expansion of deserts, and alteration of regional weather systems. Climate change has many ecosystem effects. It disrupts food webs, shifts ranges of plants and animals (*see page 77 and* ***figure 5.4.***), alters the timing of life-cycle events, and can promote the spread of pathogens (*see snowshoe hare, page 59*).

Ocean acidification is the partner to climate change. Increasing CO_2 in the atmosphere increases the amount of CO_2 that dissolves in water, thereby forming carbonic acid. Ocean waters have a natural pH of 8.2. Oceanic pH now averages 8.0 and is continuing to drop. A form of calcium carbonate, called aragonite, is used by many marine animals, including corals, echinoderms, molluscs, and crustaceans to build shells and skeletons. Increasing acidity either decreases availability of calcium carbonate for forming shells and skeletons or increases the rate of dissolution of calcium carbonate from shells and skeletons. Either way, calcifying species are adversely affected.

In 2015, 197 countries came together in Paris, France, to participate in the United Nations Framework Convention on Climate Change (UNFCCC). The Paris Agreement established the following goals:

- global average temperature will be kept well below 2°C above preindustrial levels (an increase of 1.5°C would significantly reduce impacts of climate change);
- greenhouse gas emissions will peak early in this century and reach net-zero emissions in the second half of this century;
- all parties are committed to contributing to climate change mitigation and adaptation;
- mitigation measures of individual countries will be expressed in nationally determined contributions (NDCs);
- NDCs will be reevaluated every five years; and
- countries will cooperate in achieving NDCs. (This goal recognizes the different starting points of participating countries and emphasizes the importance of developed countries leading and supporting the work of less developed countries.)

As of November, 2017, 170 of 197 participating countries have ratified the Paris Agreement.

How do we achieve these goals? The United States derives 88% of its energy from coal, oil, and natural gas. We can reduce CO_2pollution through the use of alternative fuels and carbon capture and sequestering technologies. Worldwide renewable energy use includes ethanol and biodiesel (0.5% of total energy use), wind (2%), hydropower (2%), and photovoltaics (solar) (less than 0.05%). Power generation from nuclear reactors accounts for 13% of energy production. One of the biggest problems in the United States is the construction of east-west transmission lines required for long-distance transmission of electricity. Supergrids for energy transmission from regions that are reliably sunny or windy will take years to construct. Carbon capture technologies remove CO_2 from point sources, like power plants, and sequester

Nutrient Load and Pollution

Excessive nutrient load and other forms of pollution make ecosystems uninhabitable. For example, consider the nutrients nitrogen and phosphorus. Nitrogen and phosphorus also undergo biogeochemical cycling. The reservoir for nitrogen is in the atmosphere (a gaseous cycle) and the reservoir for phosphorus is in the earth (a sedimentary cycle). Both nitrogen and phosphorus are fertilizers that promote algal growth in lakes, rivers, and oceans. Algal blooms and die-offs contribute to oxygen depletion in aquatic environments, which makes water uninhabitable for many animal species. Most nitrogen and phosphorus pollution comes from fertilizer use and agricultural run-off, including nitrogen and phosphorus pollution from concentrated animal feeding operations (CAFOs). The use of corn-based ethanol-blend fuels, while reducing our use of fossil fuels, has increased the load of nitrogen flowing down the Mississippi River to the Gulf of Mexico by an estimated 30 to 40%. No-till farming, terracing, requiring treatment of effluent from CAFOs, eating less meat, and using alternative biofuels could reduce nitrogen and phosphorus pollution dramatically.

How Do We Know?

Local Steps to Alleviating Global Problems

Most of the readers of this textbook live in developed regions of the world, principally the United States. The environmental problems facing you in the years ahead no doubt seem formidable—more so with the realization that many of the problems are largely not of your making. On the other hand, your (our) life in the developed world has a far greater detrimental impact on global environmental health than you (we) probably realize. It is estimated that the average U.S. citizen uses 25 times more resources than a person living in a developing country. This statistic means that even though population growth rates are higher in developing countries, a family in a developing country would need to have 50 children to use the same resources as a family with two children in the United States. Those of us in developed countries bear much of the responsibility for responding to environmental problems. Solutions are both global and local. We can each do our parts by learning to live humbly and harmoniously with nature. Following are 10 relatively simple steps that we can all take right now to reduce the detrimental impact of our lives on the environment:

1. Contact your public officials, urging them to support environmental legislation. The Internet sites listed at the end of this box have up-to-date information on legislation currently being debated at national and state legislatures.
2. Learn more. The listed Internet sites have a wealth of information.
3. Share the knowledge. Write your local newspaper and other media about environmental issues. Monitor their coverage of the environment. The listed Internet sites provide strategies for sharing the information in schools and other organizations.
4. Reduce your home, apartment, or dormitory energy use. It is estimated that 21% of global warming pollution results from home energy use. Use compact fluorescent light bulbs; unplug battery chargers when they are not in use; use power strips to stop energy use by electronic devices when they are not in use; buy energy-efficient appliances; turn down the thermostat; and install programmable thermostats.
5. Drive a green-friendly car. Your choice of what car you drive is probably the single most important environmental decision you will make. Assuming you drive 12,000 miles per year and average 10 miles per gallon, you will add 13.6 tons of greenhouse gas to the atmosphere and spend $3,000 on gasoline (assuming $2.50 per gallon of gasoline). If you average 30 miles per gallon, you will add 4.5 tons of greenhouse gas to the atmosphere and spend $1,000. If you average 50 miles per gallon, you will add 2.7 tons of greenhouse gas to the atmosphere and spend $600

Overexploitation of Resources

Overexploitation of resources involves using resources and organisms at a greater rate than can be sustained by natural processes. Resources can be renewable or nonrenewable. **Renewable resources** are those that can replenish themselves when used within natural ecosystems or by humans. These include forest, fishery, and game resources and some energy resources like solar and wind power. **Nonrenewable resources** do not renew themselves over meaningful time frames. These include fossil fuels, soils, freshwater aquifers, and earth minerals and metals. When nonrenewable resources are used, they can never be replaced. Overexploitation includes unbridled use of both renewable and nonrenewable resources. Land and water are considered renewable in the sense that they can be used over-and-over again, and they can recover from some misuse. They are also considered nonrenewable in the sense that neither freshwater aquifers nor soils can be replaced after long-term exploitation by humans.

Land is an exploited resource. We use 35% of the earth's land surface for agricultural purposes, and expanding agriculture is one motivation for clearing more land. Urban sprawl, the spreading of a city and its suburbs into the surrounding countryside, puts pressure on farmland and natural areas. It has many negative consequences: promotes our dependence on automobiles; inflates costs for public transportation, per-person infrastructure, and per-person use of water and energy; and causes habitat destruction. Urban sprawl disrupts wildlife corridors that maintain connectivity between populations. Connectivity of populations promotes genetic exchange between populations. It permits animals to move (usually northward) in response to climate change. Zoning, more efficient agricultural practices, efficient food distribution, and reducing meat consumption in wealthy nations can help preserve our land.

Worldwide we draw 2,600 km^3 of freshwater annually from rivers, lakes, and groundwater. Irrigation accounts for 70% of this use, industry for 20%, and domestic use for 10%. Ground and surface water resources are drying. A major aquifer in the United States, the Ogallala Aquifer, has been depleted by about 9% since 1950. It is estimated that it would take about 6,000 years to recharge this aquifer through rainfall if it were to be completely depleted. Improvements in water-use efficiency include moving to more efficient drip and precision sprinkling irrigation systems and accurately monitoring soil moisture. Shifting away from the use of water in cooling power plants to dry cooling technology and replacing old appliances, toilets, and showerheads with water efficient ones are relatively easy improvements.

Wetlands are land areas that are permanently or seasonally saturated with water. They include swamps, marshes, and bogs. Wetlands provide many ecosystem services including flood control, groundwater replenishment, water purification, and shoreline stabilization. Wetlands are very important biodiversity reservoirs. They are home to thousands of animals. Approximately 200 new species of fish are described from U.S. wetlands each year. Unfortunately U.S. wetland losses are estimated to be in excess of 50% as compared to wetland areas present at the time of European settlement (1600s). Losses are the result of urban sprawl, floodplain development, agriculture, and road building.

One of many possible examples can illustrate the impacts of urban sprawl, freshwater use, and wetland destruction. The arroyo toad (*Anaxyrus californicus*) is a small greenish-gray toad with a spotty skin (**figure 6.14**). Arroyo toads were historically found in streams and river basins in southern California and Baja, Mexico. Arroyo toads live around shallow pools and sandy streams where they breed, and tadpoles mature into adults. Adults burrow into sandbars and stream banks for shelter during the day and during the dry season. Unfortunately for the toad, its home range is also home to about 20 million humans. The toad's habitat has become the location for highways, housing developments, water reservoirs, campgrounds, and off-road vehicle parks. Dam construction has been responsible for the destruction of 40% of this species' habitat. These developments chopped the toad's range into unconnected habitat patches, and the species range has been reduced by 75%. Its current population is estimated at 3,000 individuals, and it has been listed as an endangered species by the U.S. Fish and Wildlife Service. This listing has resulted in about 100,000 hectares of critical habitat being established for the arroyo toad. This habitat includes a mosaic of breeding, foraging, and shelter habitats—all interconnected by migration corridors. The response of this toad to these measures is uncertain.

FIGURE 6.14 **The arroyo toad (*Anaxyrus californicus*).** Arroyo toads are native to southern California and Baja, Mexico. They have been listed as endangered by the U.S. Fish and Wildlife Service. Habitat for these amphibians has been disrupted by developments that support human activities. This species' range has been reduced by 75%, including the loss of important migration corridors between interconnected habitat patches.

Invasive Species

Invasive alien species are nonnative species that are introduced into an ecosystem. Invasive species can prey on native species and outcompete them for food and space (*see Nile perch, page 5*). These effects occur because ecosystems are naturally filled with organisms that have coevolved for millions of years. Native prey species may not have evolved defenses against foreign predators. On the other hand, prey species from one ecosystem that are introduced into a nonnative ecosystem may have no predators in their new environment. Uncontrolled by predators, these species often proliferate (*see page 330*). Invasive species may alter reproductive cycles of native species, introduce pathogens into ecosystems (*see page 351*), and alter ecosystem food webs. Invasive species have been accidentally released into ecosystems (*see pages 202–203 and 330*). They have also been introduced intentionally in attempts to control agricultural pests, in the form of ornamental plants, and as exotic pets that are no longer "loved."

Concluding Remarks from Two Ecological Giants

This section of chapter 6 began with quotes from Aldo Leopold and E.O. Wilson. We end with more of their wisdom. First, from *Round River: From the Journals of Aldo Leopold* (1972):

> The last word in ignorance is the man who says of an animal or plant, "What good is it?" If the land mechanism as a whole is good, then every part is good, whether we understand it or not. If the biota, in the course of aeons, has built something we like but do not understand, then who but a fool would discard seemingly useless parts? To keep every cog and wheel is the first precaution of intelligent tinkering.

Nature has inherent, inestimable value. Preserving every part of it should be a priority of every person who sees himself or herself as a part of nature—both for the survival of nature and for the survival of humanity. From E.O. Wilson in *The Diversity of Life* (1999):

> Humanity coevolved with the rest of life on this particular planet; other worlds are not in our genes. Because scientists have yet to put names on most kinds of organisms, and because they entertain only a vague idea of how ecosystems work, it is reckless to suppose that biodiversity can be diminished indefinitely without threatening humanity itself.

Section 6.7 Thinking Beyond the Facts

Building a four-lane highway through a natural area (e.g., a wetland) seems inconsequential to people who are unfamiliar with ecological principles. How can this common event be used to illustrate Barry Commoner's four laws of ecology?