# ENVIRONMENTAL SCIENCE

*Gorillas are one species whose survival is threatened by the growing human population.*

## FOCUS CONCEPT: *Interdependence of Organisms*

As you read, notice how a knowledge of biology helps us understand larger environmental processes.

BIOLOGY INTERACTIVE TUTOR Unit 7—*Ecosytem Dynamics*
Topics 1–6


23-1 *Humans and the Environment*

23-2 *The Biodiversity Crisis*

23-3 *Taking Action*

# HUMANS AND THE ENVIRONMENT

*In Chapter 22, you learned how environmental factors influence organisms within particular ecosystems. Large-scale environmental forces also have significant effects on human populations. A new field of study called* ***environmental science*** *uses biological principles to look at the relationships between humans and the Earth. Environmental science is becoming increasingly important because humans are rapidly changing the global environment.*

SECTION

23-1

OBJECTIVES

▲ Give an example of how global systems are linked together.

● Identify several effects of El Niño on human populations.

■ Describe two ways that humans have modified the composition of the atmosphere, and identify the possible consequences of these changes.

◆ Explain how future human population growth could affect the environment.

## A GLOBAL CONNECTION

You might not guess that wind patterns off the coast of Australia would have anything to do with fish harvests in South America or winter weather in the United States, but they do. What connects these events is a complex interaction between air and water currents that is first set in motion by solar energy. When the sun's rays strike air near the surface of the Earth, the molecules are heated and the air, which becomes less dense, starts to rise. As the air rises, it gets closer to outer space and eventually starts to cool. Cooling air becomes more dense and sinks. We can draw this pattern of rising and falling air using a loop called a **convection** (kuhn-VEK-shuhn) **cell.** Groups of convection cells form the system of global air circulation that helps determine climate, as shown in Figure 23-1.

In the southern Pacific Ocean, the usual pattern of convection cells creates a wind that blows from east to west and pushes warm surface water

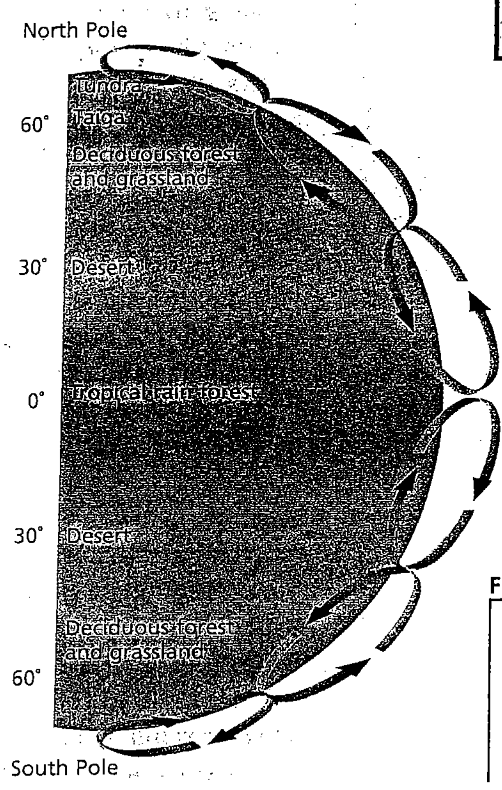


**FIGURE 23-1**

Warming and cooling air form loops called convection cells in Earth's atmosphere. These air currents influence where different ecosystems are located and also create oceanic circulation patterns.

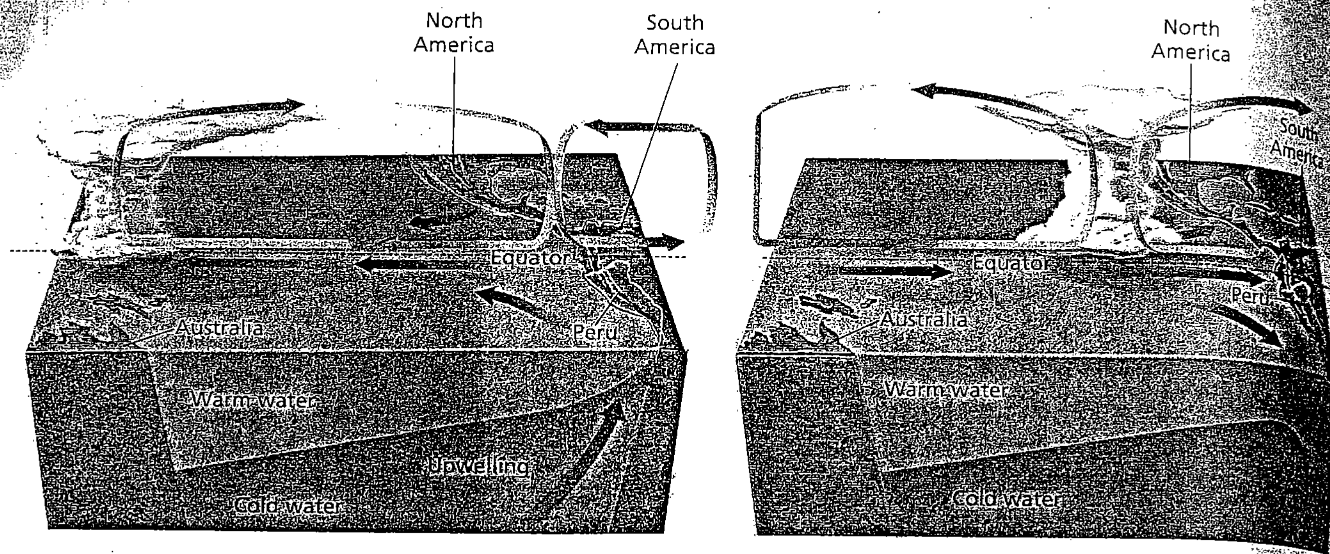


**FIGURE 23-2**

These two drawings show a comparison of water and atmospheric circulation in normal (left) and El Niño (right) years. The red arrows indicate the movement of warm oceanic currents, and the yellow arrows indicate the movement of air. In an El Niño year, the cold upwelling is blocked by warm water moving toward the coast of Peru.

from South America toward Australia, as shown in Figure 23-2. Along the South American coast, cold water rises from deeper in the ocean and replaces the warm water. This rising current is called an **upwelling,** and it brings with it organic material and nutrients that support an abundance of plankton. The plankton, in turn, support large populations of fish.

One kind of fish that is abundant in these conditions is the anchovy, a main export of the South American country of Peru and a popular pizza topping. Anchovies provide a livelihood not only to fishermen but also to packers, shippers, netmakers, boat builders, and other workers. Diving sea birds eat anchovies too. When these birds come back to shore to roost and digest their food, they excrete a white phosphorus-rich substance called guano. Some guano deposits are dug up and sold as high-quality fertilizer, another major Peruvian export.

## El Niño

The Peruvian economy, along with sea birds, depends on normal atmospheric conditions. But sometimes, usually in December, the normal east-to-west winds do not form over the Pacific Ocean. Instead, winds push warm water eastward toward the coast of South America, as illustrated in Figure 23-2. When these conditions occur, the warm surface water cuts off the upwelling of nutrients. This event is called **El Niño** (meaning "the child") because it usually happens near Christmas.

With fewer nutrients, the fish populations decline and Peruvian anchovy exports decrease. Fewer anchovies mean fewer birds and reduced guano production. Because all convection cells are linked in the atmosphere, the effects of El Niño extend beyond Peru. Under a strong El Niño, northeastern Australia can suffer summer drought, leading to reduced grain production there. The southeastern United States gets higher rainfall in El Niño years, boosting agriculture while also decreasing forest fires.

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# HUMAN INFLUENCES ON GLOBAL SYSTEMS

Global systems, such as the interconnected system of convection cells, link people and economies from across the world. Examine the following examples of how humans have unintentionally changed the global systems on which we depend.

## Declining Ozone

As you learned in Chapter 14, ozone, $O_3$, is a naturally occurring gas that is vital to life on Earth. Ozone in the upper atmosphere screens out most of the ultraviolet radiation from the sun that causes mutations. Humans, if exposed to ultraviolet radiation, suffer increased rates of skin cancer and cataracts (clouding of the lens of the eye). People are advised to wear sunscreen and sunglasses to protect against the ultraviolet radiation that is not blocked by ozone.

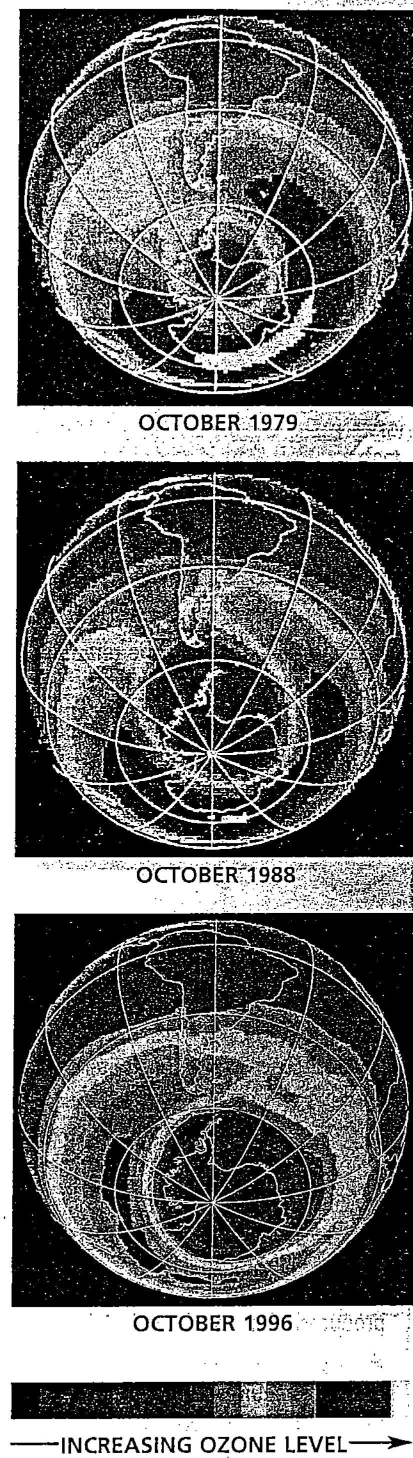
Several kinds of human-made chemicals are diminishing the ozone shield, allowing more ultraviolet radiation to reach the Earth's surface. The most important of these ozone-destroying chemicals are known as **chlorofluorocarbons,** or CFCs. Originally thought to be harmless, CFCs have been used as coolants in refrigerators and air conditioners and as the propellant in aerosol spray cans. They have also been used to make plastic-foam products and to clean electronic equipment. In the upper atmosphere, CFCs act as catalysts that break down ozone much faster than it is formed by natural processes. Scientists have estimated that a single CFC molecule can help destroy up to 100,000 ozone molecules.

Beginning in the 1980s, atmospheric measurements have indicated some alarming declines in ozone levels. Ozone destruction is most severe over the Earth's polar regions, and for a few weeks every year, an ozone "hole," a zone of very low ozone concentration, forms over Antarctica, as shown in Figure 23-3. In 1991 an international study estimated that even a 10 percent worldwide decrease in ozone levels would cause 300,000 new cases of skin cancer in humans. Other organisms, including plants and photosynthetic algae, are also harmed by high levels of ultraviolet radiation, so ozone depletion could modify entire ecosystems over time.

The evidence of widespread and worsening damage to the ozone layer led to international agreements to stop production of CFCs by the end of 1995. Because the substitutes for CFCs are initially more expensive, the developed countries are contributing to a fund to help the developing countries make the changeover. A global environmental success story, these agreements have already cut CFC production by more than 75 percent. Environmental scientists estimate that if the terms of the agreements continue to be followed, the ozone layer will start to build up again, perhaps recovering completely in 50 to 100 years. The effort to protect the ozone layer is a good example of how scientists and policy makers can work together to solve an environmental problem.

**FIGURE 23-3**

These computer-generated images are based on satellite measurements of ozone levels over Antarctica.



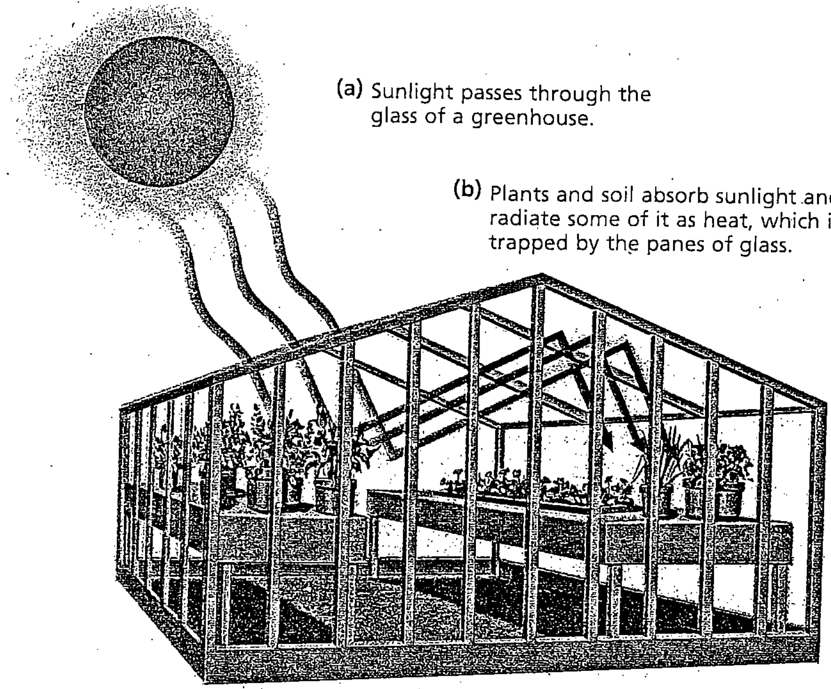



**FIGURE 23-4**

Solar energy in the form of light penetrates a greenhouse, but the reradiated heat does not immediately escape. In the atmosphere, gases such as carbon dioxide trap heat and warm the surface.

## Increasing Carbon Dioxide

Carbon dioxide, $CO_2$, is a naturally occurring gas that is a raw material of photosynthesis and a byproduct of cellular respiration. It is also released when fossil fuels, such as natural gas, coal and petroleum, are burned in homes, power plants, and motor vehicles. Around the middle of the nineteenth century, before humans began to substantially increase their use of fossil fuels, carbon dioxide levels in the atmosphere were fairly stable, at about 280 parts per million (ppm). Since 1850, carbon dioxide levels have risen nearly 30 percent, to 360 ppm, and they seem likely to increase as the world's use of fossil fuels grows. According to some projections, by the year 2100 the concentration of $CO_2$ in the atmosphere might be twice what it was in 1850.

The concentration of carbon dioxide in the atmosphere influences how much heat from the sun is trapped by the atmosphere. The atmosphere's ability to retain heat is called the greenhouse effect. As you can see in Figure 23-4, the glass in a greenhouse allows the sun's rays in but prevents heat from escaping. The same process happens in cars left in the sun with the windows rolled up.

### Quick Lab

**Calculating $CO_2$ Production**

**Materials** pencil, paper

**Procedure** A young tree can remove 11 kg of $CO_2$ from the atmosphere in a year. Each liter of gasoline burned by a car produces 3 kg of $CO_2$. Suppose you are taking a trip by car. Your round-trip mileage is 250 km, and you get 13 km/L of gas. Calculate how many young trees are needed in 1 year to remove the $CO_2$ that was produced from your single trip.

**Analysis** In 1 year, how many trees are required to remove the $CO_2$ produced by 100 cars taking the same trip and getting the same number of kilometers per liter? Discuss with your classmates whether your trip was ecologically efficient. What alternative transportation methods might be more ecologically efficient?

## Effects of Rising Carbon Dioxide Levels

If you look at climatic records derived from ice-core samples shown in Figure 23-5, it is apparent that temperature changes over the last 160,000 years correspond to changes in atmospheric carbon dioxide concentration. Scientists call this type of matching relationship a **correlation.** Because temperature changes correlate with changes in carbon dioxide level, the long-term pattern suggests that a **cause-and-effect relationship** might exist between these two variables. In a cause-and-effect relationship, a change in one variable directly leads to a change in the other variable. Even a strong correlation does not prove the existence of a cause-and-effect relationship, but experiments enable scientists to establish a connection between two variables.

It is not possible to carry out a global experiment that would conclusively demonstrate a cause-and-effect relationship between carbon dioxide levels and rising temperatures. Instead, environmental scientists rely on computer models that simulate the Earth's climate. Because so many factors besides carbon dioxide levels have to be taken into account (wind patterns, ocean temperatures, and effects of ecosystems on $CO_2$ levels, to name a few), these models are very complicated. It is like predicting the weather hundreds of years in advance.

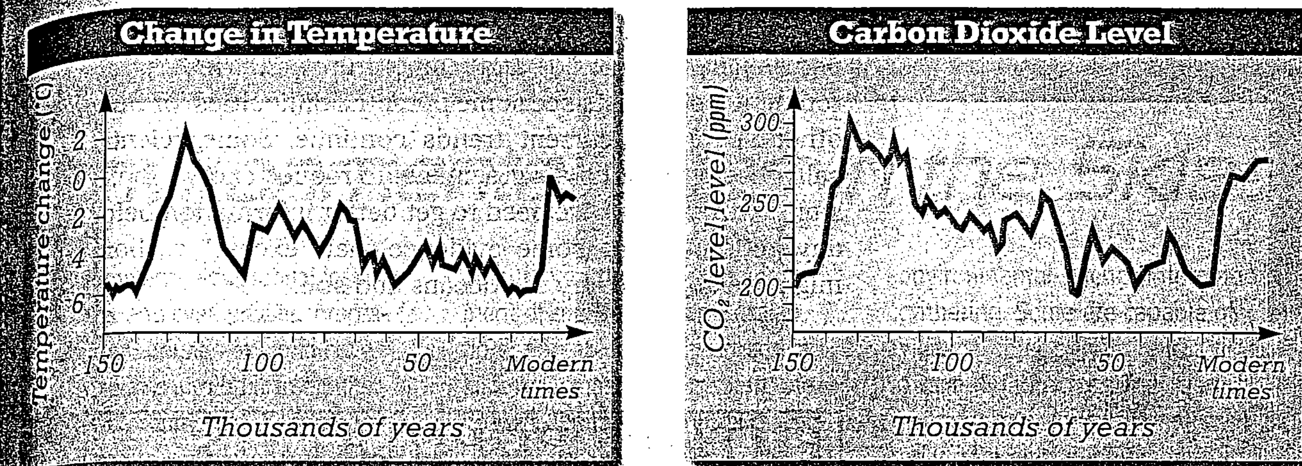



**FIGURE 23-5**

These graphs show data representing 150,000 years of Earth's climatic history. Although the correlation is not perfect, in general, high levels of carbon dioxide correlate with temperature increases and low levels correlate with temperature decreases. As of 1995, carbon dioxide levels had risen to 360 ppm, higher than any part of this record.

By varying carbon dioxide levels in these climate models, scientists can simulate the possible effects of $CO_2$ on temperature. The results of these simulations are consistent: doubling carbon dioxide concentration leads to higher average global temperatures—in the range of 1.0°C to 4.5°C (2°F to 8°F). The exact temperature change depends on the particular assumptions built into the model, but nearly all scientists studying this problem have concluded that increased carbon dioxide levels cause temperature increases in the atmosphere.

Measurements of temperatures from around the world support this conclusion. The recent rapid increase in atmospheric carbon dioxide has been accompanied by higher global temperatures, as shown in Figure 23-6. Today the average global temperature is about 0.6°C (1°F) higher than it was in 1860. An international panel of scientists notes that temperatures are expected to rise an additional 2°C (4°F) within the next century. Although this may not seem significant, this increase can have global effects on rainfall patterns, soil moisture, and sea level. These factors might shift agricultural regions of the world and disrupt natural ecosystems. Specific effects on a particular country or state cannot be predicted yet, but most models project that the effects will be felt most strongly in temperate and polar regions.

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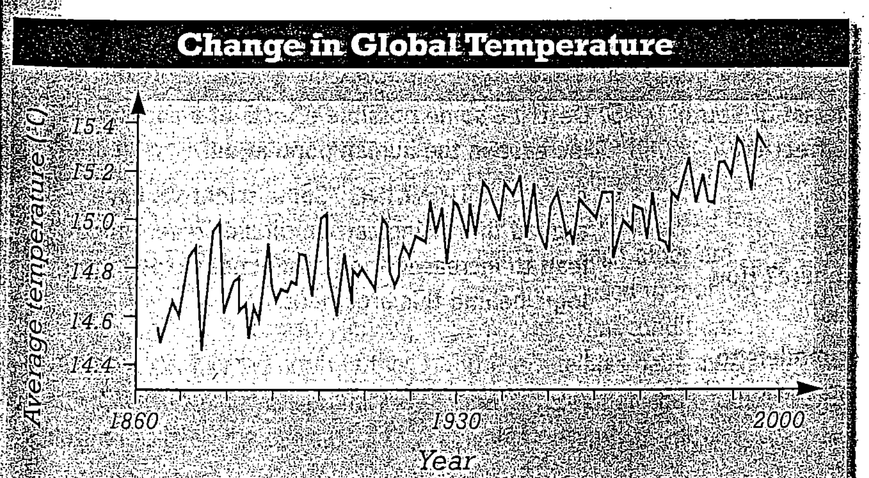



**FIGURE 23-6**

Although temperatures fluctuate from year to year, a general warming trend is evident over the last 140 years. During this same period, carbon dioxide levels have risen 30 percent, mainly due to the increased use of fossil fuels.

We do not fully understand all aspects of the relationship between carbon dioxide and temperature increases, but most environmental scientists see some potential difficulties for humans and other species if current trends continue. Some scientists have called for international agreements to reduce carbon dioxide emissions. Others think we need to get better information before taking any action, noting some evidence that "excess" carbon dioxide might be absorbed by the oceans and soil.

## FUTURE POPULATION GROWTH

You learned in Chapter 20 that the Earth's human population is currently 6 billion and growing at the rate of about 90 million people per year. The United Nations estimates that by the year 2050 the world's population could more than double, to 12.5 billion. How would a doubling of the Earth's population affect ozone levels, carbon dioxide concentrations, and other environmental conditions, such as the availability of clean water, open space, and wildlife habitats?

Although ozone levels may increase and stabilize, doubling the number of people will likely mean more fossil-fuel use and more clearing and burning of forests, which in turn will increase carbon dioxide levels and hasten global warming. Fresh water constitutes less than 3 percent of the water on Earth, and two-thirds of the world's population already lacks a reliable source of drinking water. Doubling the population could also require twice as many homes, schools, hospitals, landfills, and roads, all of which decrease the amount of undeveloped land. Humans already are using 40 percent of the net primary productivity of the Earth; if we double our use, many other organisms will be unable to survive.

### SECTION 23-1 REVIEW

1. What causes the upwelling off the coast of South America? How does this upwelling affect the economy of Peru?
2. Describe the consequences of El Niño.
3. How have CFCs affected the atmosphere? How might this change affect humans?
4. How have scientists used computer models to help understand the effects of rising carbon dioxide levels?
5. Describe some possible effects of a continued increase in the human population.
6. **CRITICAL THINKING** Some scientists have argued that rising carbon dioxide levels might lead to increased food production. Explain the logic behind this argument.

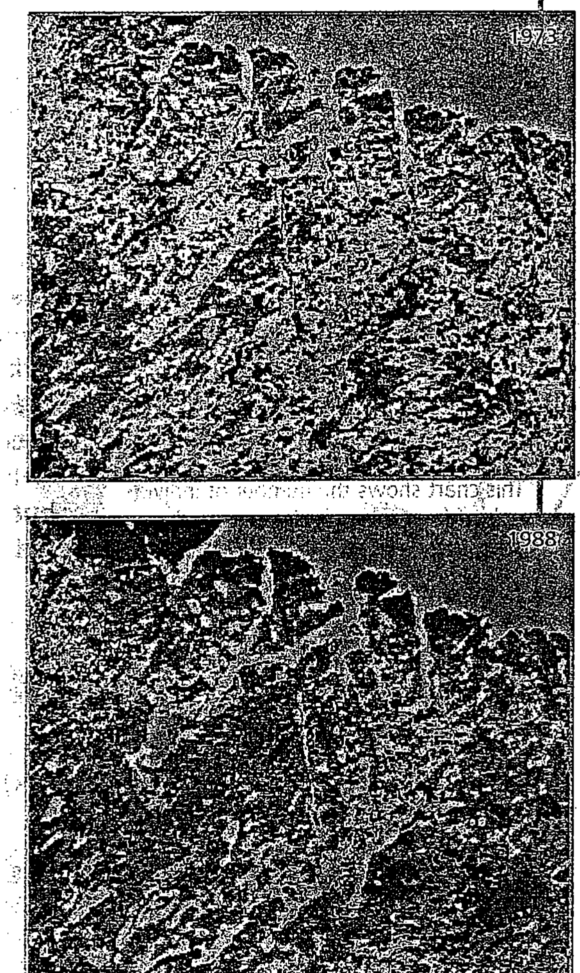
# Environmental Eyes in the Skies

Governments, educational institutions, and even private corporations from around the world have sent satellites into orbit to monitor global environmental changes. The satellites use various devices to collect and measure information about Earth's surface and relay it back to Earth, often in "real time." That is, observers on Earth can view the images at the same time the satellite's instruments are observing them.

One system of polar-orbiting satellites, which circle Earth in a north-to-south orbit each day, sends information to the National Oceanic and Atmospheric Administration. These satellites carry equipment that measures clouds, provides temperature and moisture data from Earth's surface through the atmosphere, measures the energy emitted by the sun, and measures radiation striking and leaving the Earth. The satellites also receive emergency signals from people in distress. ARGOS, a French-provided satellite system, collects information from sensors placed in various locations, such as on ships, buoys, weather balloons, and even birds and other animals. The ARGOS satellites provide both short-term information, such as storm warnings, and ongoing information, such as global changes in pollution levels and vegetation cover.

Hans Tømmervik conducts research projects in Tromsø, Norway, a busy seaport located north of the Arctic Circle. Tømmervik's primary concern has been the effect of air pollution on the natural environment of the Norwegian-Russian border area, located hundreds of kilometers east of Tromsø. In one project, Tømmervik and fellow scientists used information from remote-sensing satellites to map changes in the area's vegetation cover from 1973 to 1988. They compared vegetation-cover maps with sulfur dioxide emission levels for the same years. A time sequence of satellite images showed that the area with lichen-dominated vegetation had decreased by 85 percent over 15 years, while desert-like conditions had increased by more than five times. During the same time, emission levels of sulfur dioxide had increased dramatically. The scientists developed a pollution-impact map on the basis of the vegetation maps. The map clearly shows how the impact of pollution varies with distance from the pollution source.

Satellite monitoring of the environment has made large gains since the end of the Cold War between the United States and the former Soviet Union. Satellites that these nations previously used for spying on each other are now being used to monitor environmental conditions. These satellites have much better resolution than satellites currently used for environmental-science information gathering. Some are capable of viewing objects that are less than 15 cm (6 in.) across. The scientific community stands to benefit not only from better equipment but also from international sharing of expertise in designing sensors and interpreting data.




*Between 1973 and 1988, a satellite monitored the effects of pollution on a 10,000 km$^2$ area along the border between Russia and Norway. One of the main discoveries was that lichen-covered areas (light green on maps) decreased by 85 percent, while there was a fivefold increase in bare, eroded, and damaged areas (violet on maps).*

SECTION

23-2

OBJECTIVES

▲ Define *biodiversity*, and explain three ways to measure it.

● Describe global patterns of biodiversity.

■ Identify two strategies for conserving biodiversity in developing countries.

◆ Distinguish between utilitarian and nonutilitarian reasons for conserving biodiversity.

# THE BIODIVERSITY CRISIS

*Although some extinctions of species are natural events that have been going on since life began, environmental scientists have noted that humans are now causing species to become extinct much faster than in the past. Because extinction is irreversible and stops the evolution of future species, biologists are urgently trying to learn more about how we can conserve species.*

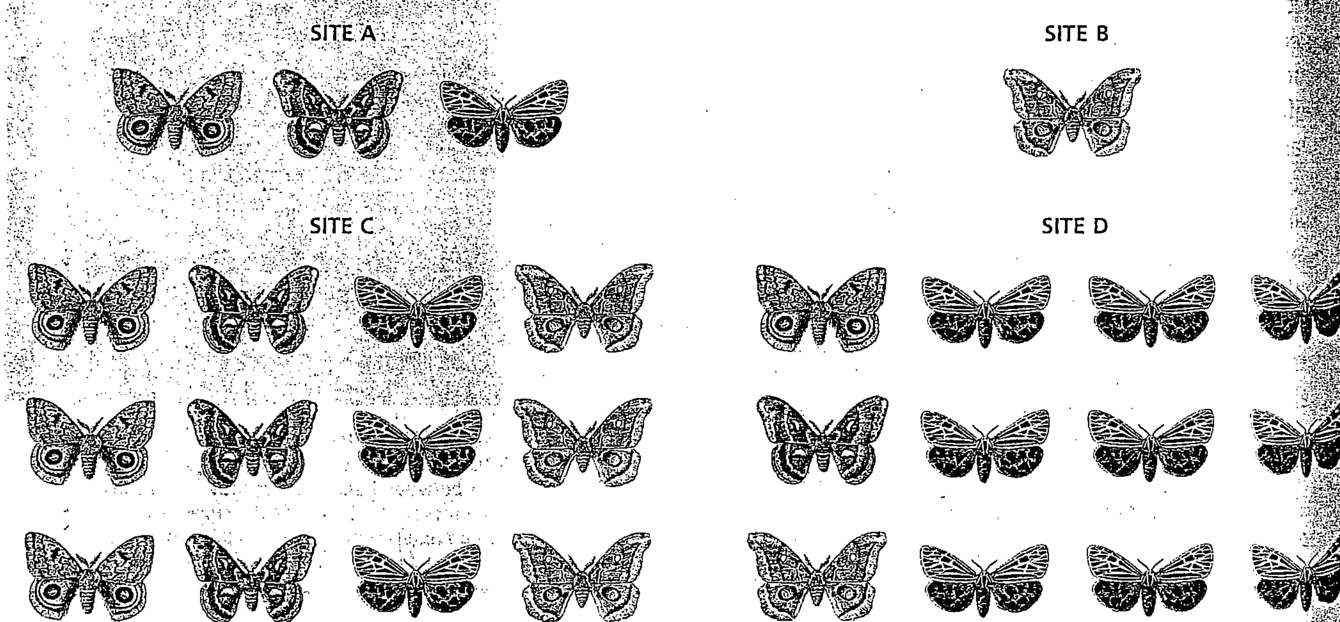
## BIODIVERSITY

**Biodiversity** refers to the variety of organisms in a given area. Biodiversity can be measured in several ways. Looking at Figure 23-7, it seems easy to say that Site A has more biodiversity than Site B and less than Sites C and D. Recall from Chapter 21 that the number of species in an area is called species richness. In this example, species richness for Site A is 3, for Site B is 1, for Site C is 4, and for Site D is 4. For quick comparisons between sites, biologists often find that species richness is a very useful estimate of biodiversity.

Now compare Site C with Site D. Each site has four moth species, but the moth communities are not the same. Site C has three individuals of each species of moth, while Site D has one individual of

**FIGURE 23-7**

This chart shows the number of individuals of four moth species captured at four sites.



each of three species and nine individuals of the fourth species. Even though the species richness (4) and the total number of individuals (12) are the same, biologists would expect these two communities to behave differently. Thus, biologists often determine how many individual organisms belong to each species, a measure called **evenness.** In our example, Site C has greater evenness than Site D. For detailed comparisons between communities, biodiversity is sometimes expressed as a quantity called species diversity (a concept introduced in Chapter 21), which combines species richness and evenness.

Because evolution depends on the presence of genetic variation within a population, as you learned in Chapter 15, some biologists would want to know the genetic makeup of each moth. With this information, biologists can calculate the **genetic diversity,** or amount of genetic variation, for each site. In the long run, genetic diversity might be the most important measure of biodiversity, but it is the one we know the least about.

## MEASURING EARTH'S BIODIVERSITY

If we use the species-richness measure of biodiversity, how much biodiversity is there on Earth? Estimates vary, but most biologists are confident that there are at least 10 million species on Earth—and possibly as many as 30 million. These are staggering numbers, especially because, in about 200 years of cataloging, scientists have named and described fewer than 3 million species.

When most people think of nature, they tend to focus on mammals. Humans seem to have a basic attraction to large mammals, especially to those that have big heads, big eyes, and a cuddly appearance like pandas. Yet mammals are a very small fraction of biodiversity. Insects and plants are far more representative of life on Earth, as illustrated in Figure 23-8.

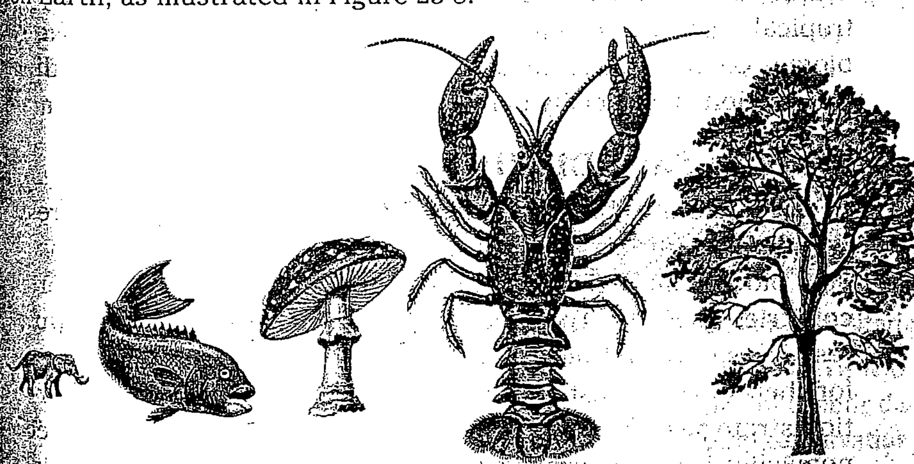
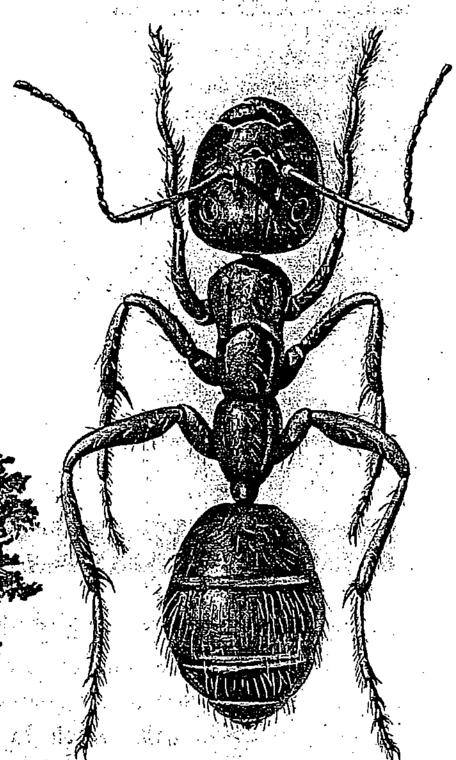
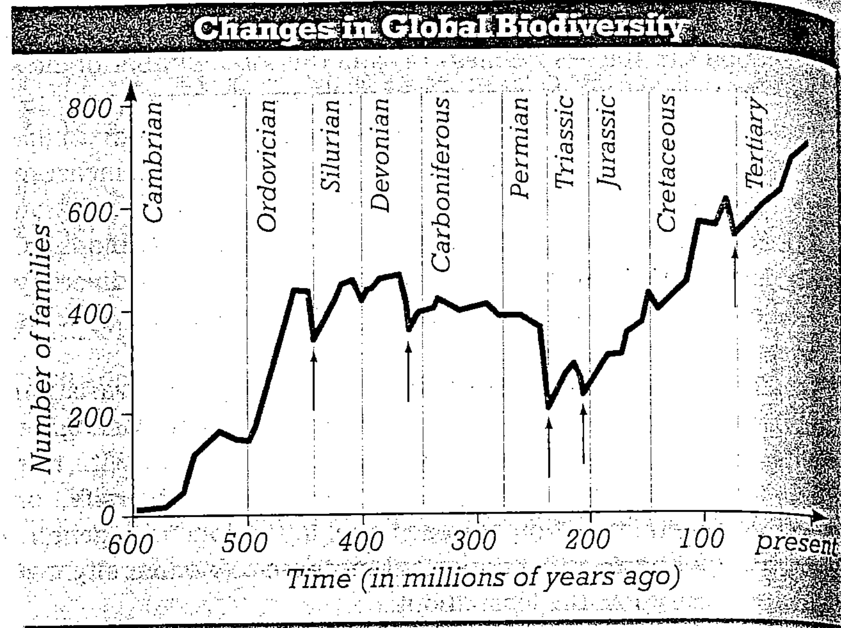




**FIGURE 23-8**
This diagram shows the known species richness of the Earth, with representatives drawn to a size that is proportional to their abundance. Although people tend to think mainly of mammals, there are many more species of insects and plants. Data from tropical forests, which are still largely unexplored, suggest that insects may represent an even greater fraction of the Earth's biodiversity than is shown here.

**FIGURE 23-9**

This graph illustrates the changes in biodiversity, measured as the number of families of marine organisms, over time. At present, biodiversity is at an all-time high. Arrows point to the five known mass extinctions. A sixth extinction is under way due to human activities.




## Reducing Biodiversity

You can see in Figure 23-9 that we are living in a time of very high biodiversity. But we are also living in a time of very rapid extinction. Biologists estimate that up to 20 percent of existing species may become extinct by the year 2030. As you learned in Chapter 15, five mass extinctions, large and relatively rapid declines in biodiversity, have occurred in the history of life. The mass extinction currently under way is different because humans are the cause. We do not know what the consequences of eliminating millions of species will be.

The greatest threat to biodiversity is the rapid destruction of natural habitats to provide for the needs and wants of the growing human population. In general, humans convert complex, self-sustaining natural ecosystems into simplified systems, such as farmland and urban areas, that cannot sustain as many species. For example, since the discovery of agriculture 10,000 years ago, more than half the world's tropical rain forests have been destroyed, and half of what remains is likely to be gone by the year 2020. Because tropical rain forests have the highest species richness of any biome, containing up to one-fifth of all species on Earth, their destruction is especially damaging to biodiversity.

## Ways to Save Biodiversity

The United States became prosperous partly by converting forests and native prairies into farms. The tropics and other regions of high biodiversity often include some of the economically poorest countries on Earth. These countries are trying to use their natural resources to build their economies and raise the standard of living for their citizens, just as the United States did. Several conservation strategies offer ways for developing countries to benefit economically from preserving their biodiversity. For example, in a **debt-for-nature swap,** richer countries or private conservation organizations pay off some of the debts of a developing country. In exchange, the developing country agrees to take steps to protect its biodiversity, such as setting up a preserve or launching an education program for its citizens. Another idea to help local people make money from an intact ecosystem is to set up a national park to attract tourists. People who want to see the ecosystem and its unique organisms will pay money for nature guides, food, and lodging. This idea is called **ecotourism.**

**Word Roots and Origins**

*utilitarian*

from the Latin *utilitas*, meaning "useful"

## THE IMPORTANCE OF BIODIVERSITY

One way to weigh the importance of biodiversity is called **utilitarian value;** it involves thinking of the economic benefits biodiversity provides to humans. For example, different plants and animals can be harvested for food, and trees can be cut to build homes and provide fuel. Some species are valuable as sources of medicines. Given that most of the world's species have not been named or described, it is reasonable to expect that some undiscovered species will also have medical benefits. Ecosystem functions crucial to our survival, such as the water cycle and nitrogen cycle, depend on living organisms. Harvard University biologist E. O. Wilson summed up the importance of biodiversity when he said, "Biological diversity is the key to the maintenance of the world as we know it."

Another way to weigh the importance of biodiversity is called **nonutilitarian value.** Basically, some people believe that life-forms have value simply because they exist, apart from any human uses of them. Intrinsic value is often associated with moral or religious beliefs that are beyond the scope of biology. Many people attach both utilitarian and nonutilitarian value to biodiversity.

Everyone is familiar with the Declaration of Independence, which led to the separation of the United States from England. Some biologists have called for a "Declaration of Interdependence," an acknowledgment of the connections between organisms, including humans, and their environments. Recognizing interdependence is what environmental science is all about.

## SECTION 23-2 REVIEW

1. Explain how species richness and evenness differ.
2. What is genetic diversity?
3. How many species of organisms are there?
4. What is a debt-for-nature swap?
5. List three utilitarian uses of biodiversity.
6. **CRITICAL THINKING** Explain why the conservation of genetic diversity is necessary for the long-term conservation of biodiversity.

SECTION 23-3

OBJECTIVES

▲ Contrast conservation biology with restoration biology.

● Describe current efforts to conserve migratory birds.

■ Discuss the biological principles and social issues related to wolf reintroduction.

◆ Explain the plan to restore the Everglades.

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TOPIC: Conservation
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# TAKING ACTION

*Although biologists have just begun to learn how nature works, they are now being called upon to help conserve threatened wildlife and restore ecosystems. Science, public involvement, and new partnerships have led to several environmental success stories. You too can contribute. Becoming aware of your local environment can link you to community action and global issues.*

## CONSERVATION AND RESTORATION BIOLOGY

As the human population has increased, the influence of humans on natural ecosystems has also increased. In the United States during the last 200 years, over 99 percent of native prairies have been replaced with farmland or urban development, and most of the old-growth forests have been cut. Loss of so much of these vegetation types has meant losses of biodiversity.

Biologists are being asked to develop plans to protect and manage the remaining areas that still have much of their biodiversity. A new discipline, called **conservation biology,** seeks to identify and maintain natural areas. In areas where human influence is greater—such as agricultural areas, former strip mines, and drained wetlands—biologists may have to reverse major changes and replace missing ecosystem components. For example, returning a strip-mined area to a grassland may involve contouring the land surface, introducing bacteria to the soil, planting grass and shrub seedlings, and even using periodic fires to manage the growth of vegetation. Dealing with a more extreme case like this is called **restoration biology.**

At present, even the best scientific efforts may not be enough to completely restore an area to its original condition. But by using their understanding of ecological principles such as energy flow, species interactions, and biogeochemical cycling, biologists can often make improvements. Let's look at three examples of conservation and restoration biology: the conservation of migratory birds, the reintroduction of the gray wolf to Yellowstone National Park, and new plans to restore the Everglades.

# CONSERVING MIGRATORY BIRDS

Imagine weighing as little as 20 g (just a bit more than a floppy disk) and flying nonstop over open ocean for 100 hours before reaching land to rest and feed. This is exactly what blackpoll warblers like the one shown in Figure 23-10 do. The blackpoll warbler is one of the 200 species of **migratory birds** that travel twice each year between North America and Latin America. Migratory birds take advantage of long days and abundant prey in northern tundra and forest ecosystems, where they breed and raise their young. Then, as autumn approaches and the food supply decreases, they fly south to warmer ecosystems that can sustain them during nonbreeding months. Examples of migratory birds you may recognize include the Canada goose, sandhill crane, barn swallow, and scarlet tanager.

Most migratory birds tend to follow generally north-south routes along rivers, mountains, and coastlines. These routes are called **flyways.** Figure 23-11 shows the four major flyways in North America. As many as 5 billion individual birds depend on suitable habitat being available at each end of their migratory journey. Some birds fly along coastlines or over land and make several stopovers for food or rest along the way. If food or habitat is lacking along their way or at their destination, they may not breed and may even die.

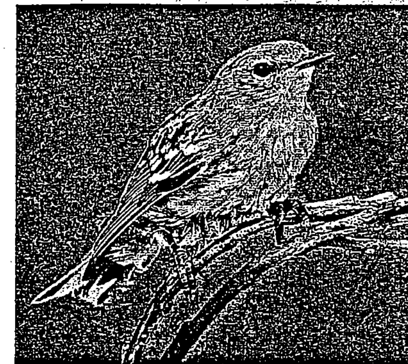


**FIGURE 23-10**
Each fall, blackpoll warblers migrate more than 2,500 km (1,600 mi) over the ocean to reach their wintering grounds in South America.

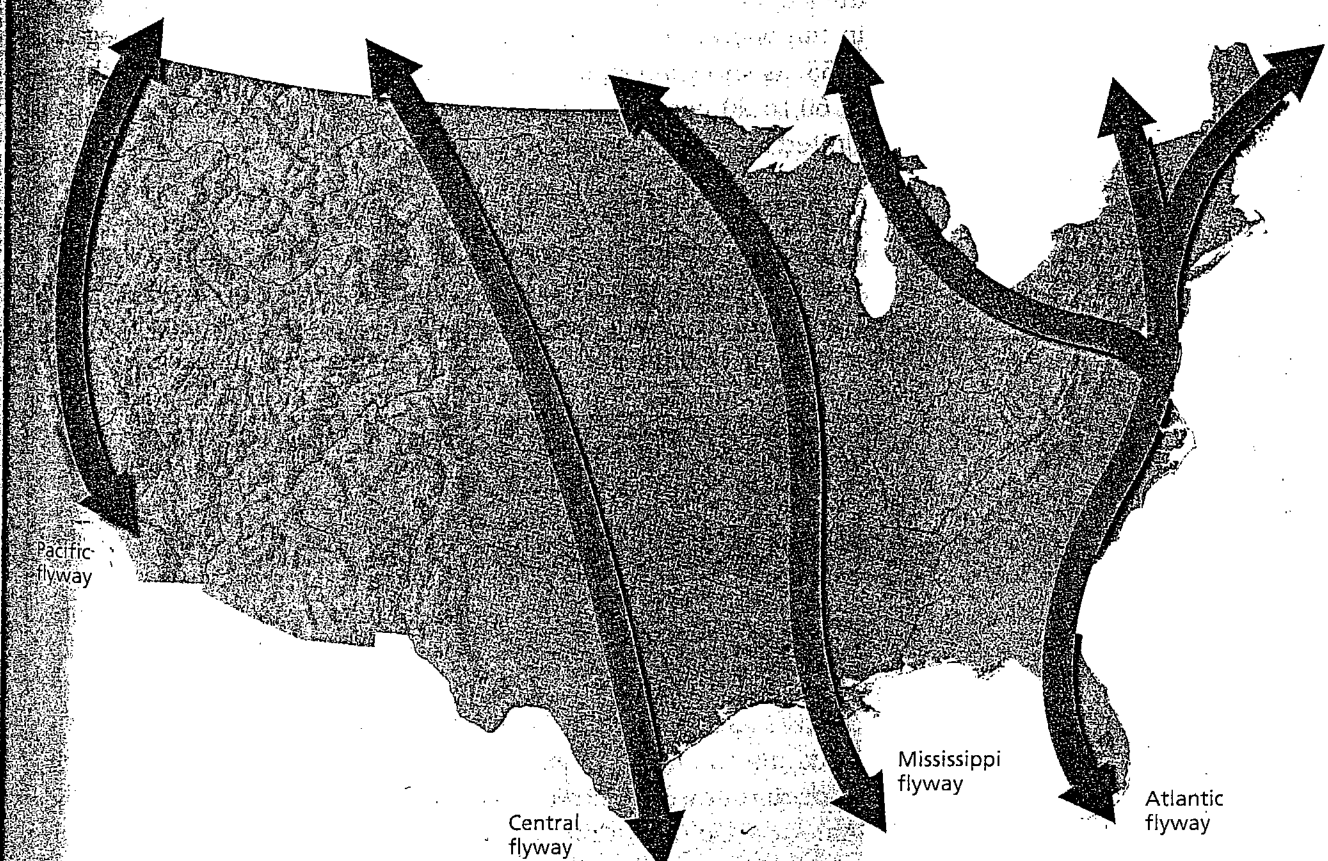
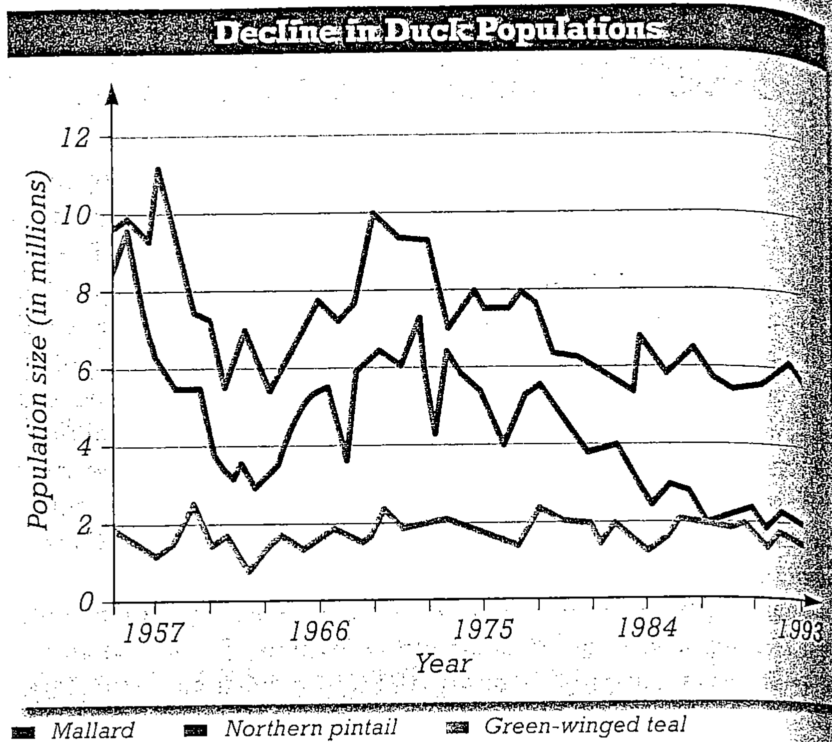



**FIGURE 23-11**
This map shows the four flyways commonly used by North American migratory birds. Birds tend to follow landscape features such as rivers, mountains, and coastlines.

FIGURE 23-12. Nationwide surveys of breeding populations of ducks indicate long-term declines in some species.




In recent years, scientists, with the help of outdoor recreationists such as hunters and birdwatchers, have documented significant declines in the populations of some migratory birds, including ducks, shorebirds, and songbirds. The number of ducks recorded in the winter of 1993 was the lowest since the surveys began, in 1955, as shown in Figure 23-12. This period was marked by the loss of 60 to 90 percent of prairie wetlands and over 50 percent of all United States wetlands.

## Saving Critical Habitat

In 1903, President Theodore Roosevelt established the first national wildlife refuge, to conserve wading birds in Florida. As we have learned more about the preferred travel routes of migratory birds and their habitat and food requirements, biologists have helped propose and develop new wildlife refuges at critical places along the flyways. There are now 500 refuges in the United States, covering about 4 percent of the total area of our country. The refuges are also home to 220 species of mammals, 250 species of reptiles and amphibians, and 200 species of fish, including one-third of all the species on the threatened and endangered species lists.

Because migratory birds also depend on winter habitats outside the United States, conservation efforts have to be international. Migratory songbirds are the focus of a new U.S. Fish and Wildlife Service program, called Partners in Flight–Aves de las Americas, covering the United States and Mexico. The Western Hemisphere Shorebird Reserve Network operates in Central America and South America. Deforestation and coastal development projects remain major threats to migratory birds in these areas.

# REINTRODUCTION OF THE WOLF

Gray wolves, shown in Figure 23-13, formerly ranged over most of the United States. For nearly a century, wolves were shot, trapped, and poisoned by people who feared for their own safety or who wanted to protect their livestock. Today the gray wolf is an endangered species, protected by law. In the contiguous 48 states, it is found primarily in Montana and Minnesota. The 1995 total population of wolves in these states was about 2,500 animals. Alaska and Canada have approximately 62,000 wolves.

The current status of wolves in the United States has much to do with human attitudes. Many people fear wolves because of childhood stories. Although sick wolves and wolf-dog hybrids have attacked people, there is no documented case of a healthy wild wolf ever killing a person in North America. Some ranchers regard wolves as threats to their livelihood. As humans have reduced natural-prey populations, some wolves have occasionally attacked livestock to survive. However, only a tiny percentage of livestock in the United States is ever lost to wolf predation. Other people associate positive qualities with wolves. Some view the wolf as a symbol of wilderness, even though wolves are adaptable and do not require wilderness areas to survive.

To a biologist, the wolf is a top carnivore that is dynamically involved with prey species, such as elk and moose. Restoration ecologists became interested in reintroducing wolves to Yellowstone National Park, shown in Figure 23-14, because until about 60 years ago wolves were the top predators of deer, moose, and elk within the park. With the eradication of the wolf—and because no hunting is allowed in national parks—elk populations had grown so large that they may have exceeded the carrying capacity of the park. A proposal was made to reintroduce the wolf to help control elk numbers, to restore a well-known species to the park, and to increase enjoyment of the park for its 3 million annual visitors.

**FIGURE 23-13**

The gray wolf is an endangered species that is the ancestor of the domestic dog. Adult wolves weigh about 45 kg (100 lb) and are about 2 m (6 ft) long from the nose to the tip of the tail. Wolves are social and commonly form packs with two to eight members.

**internetconnect**

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**TOPIC:** Wolf
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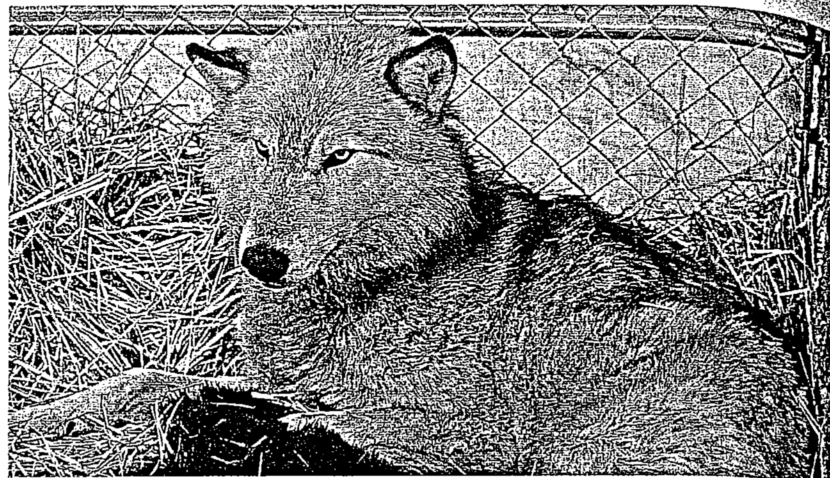
**KEYWORD:** HM455

**FIGURE 23-14**

Yellowstone National Park is the oldest national park in the United States. Wolves lived there until about 60 years ago, when they were exterminated by hunting.

FIGURE 23-15
Before being released in Yellowstone Park, the wolves were kept in pens for three months to allow them to become accustomed to their new surroundings. This strategy is called soft release.



### The Wolf Reintroduction Plan

After many years of public hearings involving people with a wide range of opinions, the National Park Service agreed to reintroduce wolves to Yellowstone. Special precautions were taken to protect the interests of ranchers opposed to the effort. First, ranchers are permitted to kill wolves that are seen attacking their livestock. Second, individual wolves that become a nuisance to humans will be relocated. Third, a private conservation organization, Defenders of Wildlife, set up a $100,000 fund to reimburse ranchers for any economic losses caused by wolves. This group also offers $5,000 to private landowners who agree to let wolves breed on their property. These financial arrangements were key factors in the approval of the reintroduction program.

Before reintroduction, biological information about wolves and Yellowstone was gathered to give the wolves their best chance of survival. In 1995, 14 wolves from Canada were placed in pens at release sites within the park, as shown in Figure 23-15. Fifteen more were released in central Idaho. In 1996, 17 more wolves were released in Yellowstone, and though 11 wolves were killed (some illegally), about 20 pups from both years survived. As of January 1997, the total number of wolves in and around Yellowstone was 40, and their breeding success continues to be monitored.

## RESTORING THE EVERGLADES ECOSYSTEM

An enormous amount of biological information must be gathered in order to reintroduce a single species into an ecosystem and monitor it over time. But imagine what is involved in restoring an entire ecosystem that has been severely damaged. A new federal, state, and local partnership has been formed to restore one of the largest and most species-rich national parks in the United States—the Everglades, shown in Figure 23-16.

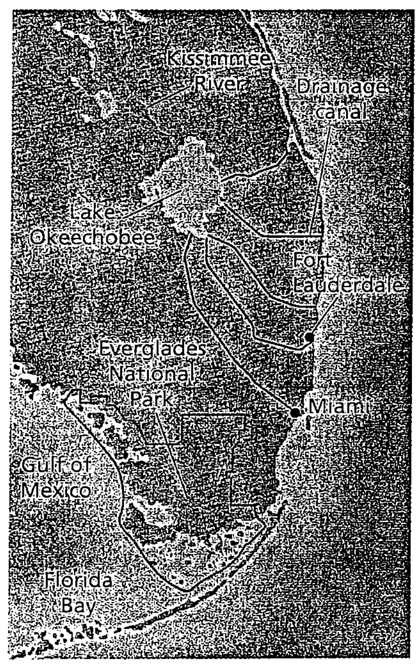
Early in this century, land developers were attracted to the large beaches and semitropical climates of southern Florida. They found extensive wetlands that were hard to build on and mosquito populations that discouraged new residents. Over time, a series of drainage canals was dug to intercept water moving south from Lake Okeechobee and divert it to the ocean, drying out the land. The non-native melaleuca tree was also planted to take large amounts of water out of the soil.

At that time, few people could foresee the ecological consequences of these actions, but Marjorie Stoneman Douglas did. She helped acquire land to create Everglades National Park and in 1947 wrote a book, *The Everglades: River of Grass,* that explained how the Everglades functioned. It is not stagnant water, but rather a unique, slow-moving river 80 km (50 mi) wide and 15 cm (6 in.) deep. The Everglades is nearly flat and is dominated by saw grass, yet it is home to over 100 species of water birds. Douglas led a lifetime crusade for the Everglades, which in just 50 years experienced a 50 percent reduction in the amount of wetlands, a doubling of salinity in Florida Bay that killed sea grass and shrimp nurseries, and a 90 percent reduction in populations of wading birds. The diversion of water also prevented the ground water from being replenished, creating water shortages for farmers and residents of Miami. Rain washed fertilizers from agricultural fields and polluted the water that did make it to the park. Heavy metals, such as mercury, poisoned park life.

The newly approved 20-year plan for the Everglades ecosystem includes eliminating some of the drainage canals, restoring the Kissimmee River to its original channel, cutting back stands of melaleuca trees, and purchasing more than 40,000 hectares (100,000 acres) for park protection. It is the most ambitious ecosystem-restoration project attempted in the United States.

**FIGURE 23-16**

Everglades National Park contains only about 20 percent of the Everglades ecosystem. The map below shows some of the key features related to the decline and restoration of Everglades National Park.



## GETTING INVOLVED

It is important for individuals to get involved in conservation, and the best place to start is at home. The first step is to learn about your local environment. For example, apply these questions to where you live.

1. *Name five native plants, and determine their seasons. Can they be used for landscaping homes or businesses?*
2. *Name five resident birds and five migratory birds. Are there any special laws that protect them?*
3. *Name two major agricultural crops. How do farmers or ranchers obtain water for crops or livestock?*
4. *Trace the path of water that you use from when it falls as precipitation to when it flows from your faucet. Where does the water go after you have used it, and how is it treated?*
5. *Name three endangered species in your area. If any species have become extinct, what was the cause?*
6. *Trace the path of garbage after it is collected. Does your sanitation department support recycling?*
7. *Describe the primary geological processes that helped form the land where you live. If the land was shaped by water, wind, glaciers, or volcanoes, are any of these still contributing to geologic change?*
8. *Find the names and addresses of two nongovernment conservation associations that are active in your region. Will they allow you to act as a volunteer?*

Exploring these questions may lead you to your own ideas about what you can do to maintain biodiversity or improve the ecological integrity in your area. A new environmental field, called **urban ecology,** involves people who are interested in the challenge of increasing biodiversity in the most heavily developed areas.

## SECTION 23-3 REVIEW

1. How are conservation biology and restoration biology different? How are they similar?
2. Why are some populations of migratory birds declining?
3. Give three reasons why wolves are being restored to Yellowstone National Park.
4. What rules have been made to protect the interests of ranchers concerned about wolves?
5. How did the diversion of water from the Everglades lead to environmental problems?
6. **CRITICAL THINKING** What benefits might people living near Yellowstone National Park receive from the reintroduction of wolves?

# CHAPTER 23 REVIEW

## SUMMARY/VOCABULARY

**23-1**

- Currents of air and water are linked into a global system that is responsible for climate.
- El Niño events occur when the normal east-to-west winds across the southern Pacific ocean reverse, causing a variety of effects on organisms worldwide, including humans.
- Over a short time period, humans have affected global systems, including altering the composition of the atmosphere by decreasing ozone levels and increasing carbon dioxide levels.
- Industrial chemicals called CFCs are destroying the ozone layer. A treaty to ban CFC production has been signed.
- From the results of computer models of the atmosphere, a large majority of scientists have concluded that increased carbon dioxide levels have resulted in warmer surface temperatures on the Earth. Scientists expect temperatures to continue to rise as fossil fuel use and carbon dioxide levels increase.

**Vocabulary**

cause-and-effect relationship (444)
chlorofluorocarbons (443)
convection cell (441)
correlation (444)
El Niño (442)
environmental science (441)
upwelling (442)

**23-2**

- *Biodiversity* refers to the variety of life found in a given area and can be measured in different ways, including by species richness, evenness, and genetic diversity.
- Scientists estimate that there are at least 10 million species on Earth and may be as many as 30 million. Scientists have described fewer than 3 million species so far.
- Insects and plants make up the majority of species on Earth, especially in tropical rain forests, which are rapidly being destroyed. Two new ideas for conserving tropical biodiversity are debt-for-nature swaps and ecotourism.
- People value biodiversity for utilitarian reasons, which emphasize economic benefits from species. Some of these benefits include medicines, foods, and other useful products, as well as ecosystem services. Nonutilitarian reasons for conserving biodiversity draw on the assertion that living things have intrinsic value. This assertion often derives from moral or religious beliefs.

**Vocabulary**

biodiversity (448)
debt-for-nature swap (450)
ecotourism (451)
evenness (449)
genetic diversity (449)
nonutilitarian value (451)
utilitarian value (451)

**23-3**

- Conservation biology and restoration biology are two new disciplines. Conservation biologists are concerned with identifying and maintaining areas that are still relatively undisturbed, whereas restoration biologists are usually involved with repairing badly damaged ecosystems.
- Populations of some migratory birds appear to be in decline due to habitat destruction by humans, but they are being helped by new refuges and international partnerships.
- After a 60-year absence, the gray wolf has been successfully reintroduced in small numbers to Yellowstone National Park to help control elk populations and to increase public enjoyment.
- A new 20-year plan to restore the Everglades ecosystem has recently been approved.

**Vocabulary**

conservation biology (452)
flyway (453)
migratory bird (453)
restoration biology (452)
urban ecology (458)

# REVIEW

## Vocabulary

1. Define the term *environmental science*.
2. What are flyways?
3. What chemical elements would you expect to find in chlorofluorocarbons?
4. Describe ecotourism.
5. What is an upwelling, and what connection does it have to El Niño?

## Multiple Choice

6. Which of the following is a consequence of El Niño? (a) decreased anchovy production (b) greater number of fires in the southern United States (c) increased guano production (d) ozone depletion
7. Ozone protects organisms from (a) meteor impacts (b) harmful radiation (c) salt depletion (d) cold temperatures.
8. Which of the following is not a use for CFCs? (a) fuel (b) coolant in refrigerators (c) propellant in aerosol cans (d) cleaning electronics.
9. Since 1850, carbon dioxide levels have (a) decreased by 30 percent (b) remained about the same (c) increased by 30 percent (d) not been measured accurately.
10. Which of the following is *not* true of biodiversity?
    (a) It is decreasing.
    (b) It consists mostly of mammals and reptiles.
    (c) It has declined sharply at least five times in the past.
    (d) It is higher in tropical rain forests than in any other biome.
11. Biologists estimate that most species on Earth are (a) insects (b) plants (c) mammals (d) fungi.
12. Benefits from biodiversity include (a) medicines (b) useful products (c) water purification (d) all of the above.
13. Stopovers are used by migratory birds to (a) breed (b) seek new habitat (c) avoid predators (d) feed and rest.
14. Wolves (a) are carnivores (b) need wilderness areas (c) are usually solitary (d) usually attack humans.
15. Which of the following is true about the Everglades ecosystem?
    (a) It is a stagnant swamp.
    (b) It has doubled in size over the last 50 years.
    (c) It supports very few species.
    (d) It has been damaged by pollution.

## Short Answer

16. Explain how convection cells are associated with biomes.
17. What happens during El Niño? Describe two ways that El Niño affects the economy of countries other than Peru.
18. What do environmental scientists mean by *interdependence*? Give an example of interdependence from this chapter.
19. Explain the difference between a correlation and a cause-and-effect relationship. How can scientists distinguish between the two?
20. How could future human population growth affect the environment?
21. Describe some of the different attitudes toward wolves. How have these attitudes affected the status of wolves?
22. Which of the communities in the table below has the highest species richness? the greatest evenness? Explain your answers.

**Species Richness and Evenness**

*Number of individuals of each species*

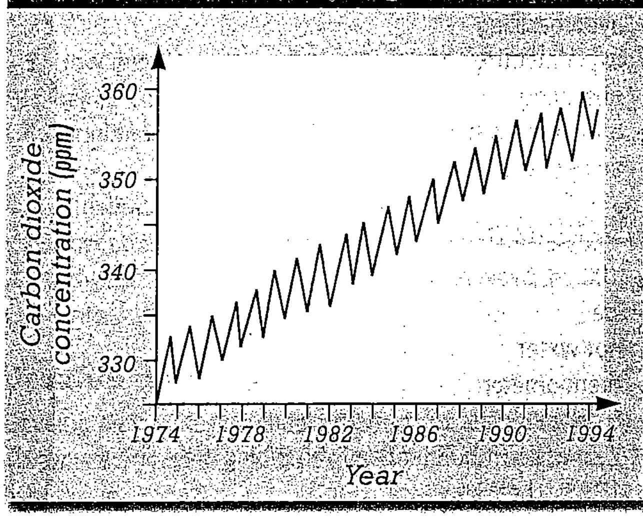
| Community | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| A | 7 | 1 | 1 | 1 |
| B | 3 | 3 | 4 | 0 |
| C | 0 | 9 | 0 | 1 |

23. Unit 7—*Ecosystem Dynamics*
    Write a report summarizing ways that humans can work to reduce the depletion and pollution of ground water. How would more efficient use of ground water benefit ecosystems?

## CRITICAL THINKING

1. You are aware of some of the connections between plankton, anchovies, humans, and birds. Suggest other species interactions that are likely to be influenced by El Niño.
2. The formation of the ozone layer depended on the presence of oxygen in the atmosphere. Drawing on what you have learned about the history of life, explain how organisms affected and were affected by the forming ozone layer.
3. There are no substitutes for clean, fresh water, which is in short supply worldwide. Environmental scientists think fresh water may become a limiting factor on human population growth. Explain how you could estimate Earth's carrying capacity for humans based just on the availability of fresh water. What information do you need in order to make this estimate? How might technological advances change your estimate?
4. What question would you add to the list shown on page 458? Explain your choice. Share your question with your classmates.
5. As part of the global treaty to eliminate CFCs, developed countries are contributing to a fund to help the developing countries buy CFC substitutes. What benefits do the developed countries receive from this investment?
6. It is a widely held belief that the birth rate declines when countries make progress toward industrialization. However, birth rate has declined in Sri Lanka and Costa Rica, countries with minimal industrial development. How might these data be explained?
7. Look at the graph below. Notice that although the long-term trend is toward higher carbon dioxide levels, the carbon dioxide concentration fluctuates during each year, falling in the spring and summer and rising in the fall. What do you think causes this fluctuation?

**Increase in $CO_2$ Levels**




## EXTENSION

1. In 1995, three scientists—Paul Crutzen, Sherwood Rowland, and Mario Molina—were awarded the Nobel Prize in chemistry for their work on the ozone layer. Use library resources or an on-line database to research each scientist's contribution to our understanding of the ozone layer. Write a short report that summarizes what you have learned.
2. Form a cooperative team with another member of your class. Work with your partner to answer the questions listed on page 458. You may need to consult several sources of information, including the library, an on-line database, local government agencies, and a nearby university, zoo, or botanical garden. When you have answered all of the questions, prepare a poster that displays what you have learned.
3. Read "In the Wake of the Spill" in *National Geographic,* March 1999, on page 96. Describe the ecological disaster that occurred in Alaska's Prince William Sound just after midnight on March 24, 1989. Which was more effective in the recovery of the ecosystem, nature or cleaning crews? Explain. What other unrelated ecological changes are happening in Alaska?

# Testing the Effects of Thermal Pollution

## OBJECTIVES

- Model the effects of thermal pollution on living organisms.
- Apply the underlying scientific principles to environmental issues.

## PROCESS SKILLS

- hypothesizing
- experimenting
- observing
- organizing data
- analyzing data

## MATERIALS

- 400 mL beakers, 2
- ice
- hot water
- thermometer
- U-shaped glass tubing, 30 cm long
- 2 corks to fit both ends of the tubing
- 125 mL beaker
- water
- *Paramecium* culture
- hand lens
- stopwatch or clock
- glass-marking pen or wax pencil

## Background

1. Some power plants use water from rivers as a coolant. After the water is used, it is much hotter than the water in the river.
2. What is a pollutant?
3. How can heat be considered a pollutant?
4. How can power plants release nonharmful water?

## Procedure

1. Discuss the objectives of this investigation with your partners. Develop a hypothesis concerning the effect of temperature on *Paramecium*.
2. Design an experiment using the given materials to test your hypothesis. In your experiment, *Paramecium* will be contained in the U-shaped tube. One large beaker will be filled with ice, and the other large beaker will be filled with hot water. Other materials that you can use in your experiment are listed in your materials list.
3. In designing your experiment, decide which factor will be an independent variable. Plan how you will vary your independent variable. In your lab report, list your independent variable and your method of varying it.
4. Decide which factor will be the dependent variable in your experiment. Plan how you will measure your dependent variable. In your lab report, list your dependent variable and your method of measuring it.
5. In most experiments, a control is necessary. Plan your control, and describe it in your lab report.
6. Discuss your planned experiment with your teacher. Proceed with your experiment only after you have received your teacher's permission to do so.
7. **CAUTION Water hotter than 60°C can scald. Be careful handling hot water, and alert your teacher if you burn yourself.** Fill a 400 mL beaker with ice and water. Make sure that ice remains in the beaker for the entire experiment. Fill another 400 mL beaker with 60°C tap water.
8. In a 125 mL beaker, gently swirl 20 mL of water and 20 mL of *Paramecium* culture. Your teacher will provide aged tap water or spring water for you to use during this step. (Chlorinated water would kill *Paramecium*.)
9. While your partner holds the test tube steady, carefully pour the *Paramecium*-and-water mixture into the U-shaped tube. Fill the tube completely, leaving just enough room for a cork at each end of the tube. Make sure there are no large air bubbles in the tube. Place a cork at each end of the tube.
10. Create a table similar to the one at right to record your data. For example, the table below is designed to

record the number of *Paramecia* in three parts of the U-shaped tube over time. Design your data table to fit your own experiment. Remember to allow plenty of space for recording your data.

11. Proceed with your experiment, using the tube, ice water, hot water, and hand lens to observe any response of *Paramecium* to the environment.
12. As you conduct your experiment, record your results, including the number of *Paramecium* and the time involved, in your data table. Organize your data so that others reading your lab report will be able to understand the results of your experiment.
13. Clean up your materials and wash your hands before leaving the lab.

## Analysis and Conclusions

1. Did the results of your experiment support your hypothesis? Explain your answer.
2. What effect did heat and cold have on *Paramecium* in your experiment?
3. What evidence do you have that *Paramecium* preferred one temperature range to another?
4. What are some possible sources of error in your experiment?
5. How might a pollutant cause an increase in the number of organisms? Explain.
6. Judging from your experiment, how do you think other organisms might react to a change in water temperature?
7. How could a power plant change the type of organisms that live in the water where it releases its cooling water?

## Further Inquiry

Develop a hypothesis about the effects of acid rain on *Paramecium,* and design an experiment to test your hypothesis.

**OBSERVATIONS OF PARAMECIA**

| | | Number of *Paramecia* | | |
|---|---|---|---|---|
| | | **Cold end** | **Hot end** | **Middle** |
| Elapsed time (seconds) | **0** | | | |
| | **15** | | | |
| | **30** | | | |
| | **45** | | | |
| | **60** | | | |
| | **75** | | | |