6-1 A Changing Landscape

About 1600 years ago, people from Polynesia began settling in the islands of Hawaii. These island people were accustomed to limited living space, so they farmed and fished with limited resources in mind. To cut down a coconut palm, a person had to plant two palm trees in its place. Fishing for certain species was prohibited during the season in which the fishes reproduce. The first Hawaiians maintained the ecosystem in such a way that it continued to provide fresh water, fertile soil, and the other resources they needed to survive. Their society was self-sufficient.

Even though they respected the land, these early settlers changed Hawaii's ecology. They cleared forests for farmland and introduced nonnative crop plants, along with animals such as pigs and rats. Eventually, as a result of the Polynesian settlers' activities, many native plants and animals became extinct.

Beginning in the late 1700s, new settlers began to arrive in Hawaii. These new settlers, who eventually included Americans, Europeans, and Asians, continued the process of change begun by the Polynesians. For example, farmers cleared vast areas to grow sugar cane, pineapples, and other crops, and they used large amounts of water for agriculture.

Hawaii today is very different from the islands the Polynesians settled. Many native species, such as the bird in **Figure 6–1**, are becoming scarce. Although the islands boast some of the wettest spots on Earth, agricultural practices have seriously depleted drinking water in places. Because of overfishing, some fish species that were once common are now rare. And Hawaiians today, unlike their Polynesian predecessors, must import some necessities, including part of their food, that were once provided by local ecosystems.

Guide for Reading

Key Concept
- What types of human activities can affect the biosphere?

Vocabulary
agriculture
monoculture
green revolution

Reading Strategy: Finding Main Ideas
As you read, make a list of facts that support the statement "The spreading influence of humans can and does affect the biosphere."

Earth as an Island

The history of humans in Hawaii offers an important lesson for the twenty-first century. In a sense, Earth, too, is an island. All of the organisms—including humans—that live on Earth share a limited resource base and depend on it for their long-term survival. We all rely on the natural ecological processes that sustain these resources.

To protect these resources, we need to understand how humans interact with the biosphere. You have learned about energy flow, chemical cycling, climate, and population-limiting factors. You must also understand how scientific models can be used to make predictions about complex systems. Studies of islands like Hawaii are important to people who don't live on an island—or don't think they do.

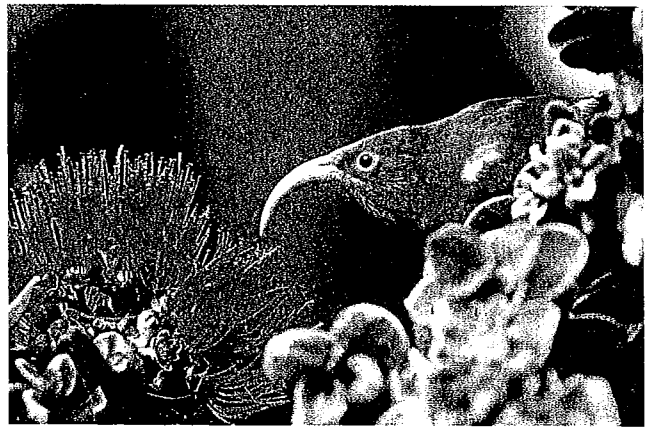
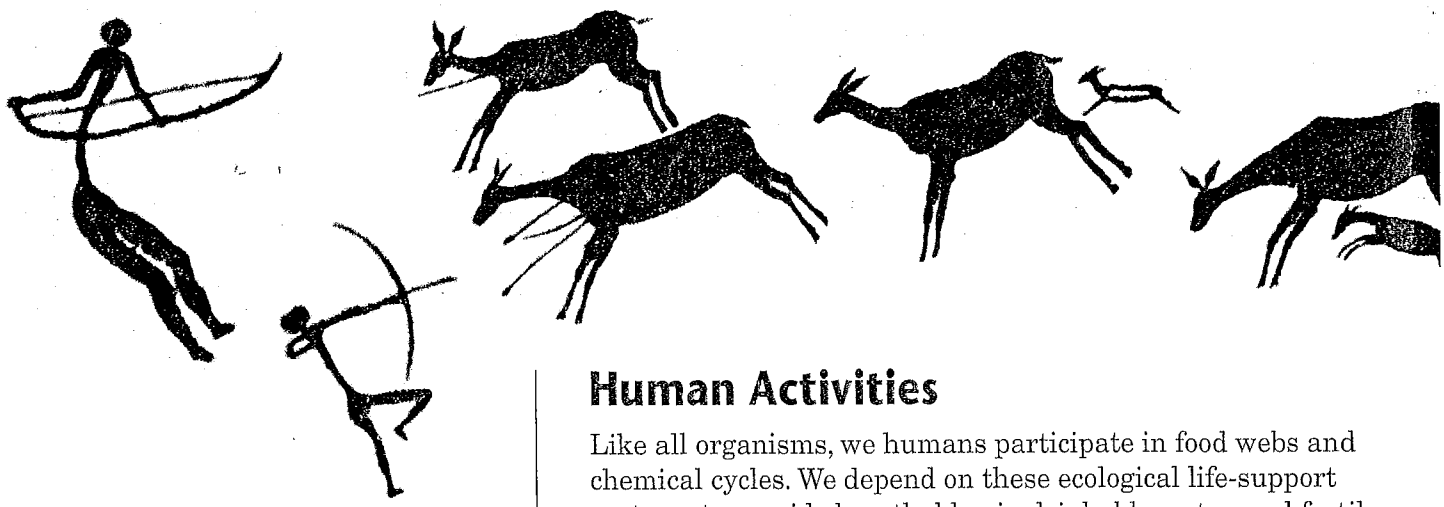


Figure 6–1 The iiwi, or Hawaiian honeycreeper, is one of the most beautiful birds in Hawaii. Like many native species in Hawaii, the iiwi is becoming scarce. Disease, habitat loss, and predation by introduced animals have taken their toll on the species. **Inferring** *Based on the photograph, what can you infer about the iiwi's niche?*



▲ **Figure 6–2** People of the Paleolithic, or Stone Age, relied on hunting and gathering for their existence. This cave painting from Northern Spain shows ancient hunters slaying a herd of deer with bows and arrows. **Hunting and gathering are among the many human activities that have changed the biosphere.**

Human Activities

Like all organisms, we humans participate in food webs and chemical cycles. We depend on these ecological life-support systems to provide breathable air, drinkable water, and fertile soil that supports farming. In addition, ecosystem processes provide us with "services" such as storage and recycling of nutrients. Ecologists refer to these necessities as "ecosystem goods and services" because they have real value to us as individuals and societies. If we do not get these goods and services from the environment, we will need to spend money to produce them.

Since we depend on ecosystem goods and services, we must be aware that human activities can change local and global environments. According to a recent study, global human activities use as much energy, and transport almost as much material, as all Earth's other multicellular species combined. We have become the most important source of environmental change on the planet. **Among human activities that affect the biosphere are hunting and gathering, agriculture, industry, and urban development.** We do not yet fully understand how human activities affect ecosystems. Happily, ecological research can help us understand and manage our impact on the environment.

▼ **Figure 6–3** Like his Stone Age predecessors, this modern subsistence hunter from the Asmat tribe in New Guinea uses bows and spears. Other subsistence hunters may use modern tools like guns or motorized vehicles. **Predicting** *What effects might subsistence hunters have on the environment in which they live?*

Hunting and Gathering

For most of human history, our ancestors obtained food by hunting and gathering. They hunted birds and mammals and fished in rivers and oceans. They gathered wild seeds, fruits, and nuts. Even these prehistoric hunters and gatherers changed their environments. For example, some scientists hypothesize that the first humans to arrive in North America about 12,000 years ago caused a major mass extinction of animals. Woolly mammoths, giant ground sloths, and saber-toothed cats all became extinct. In addition, species that once lived in North America—cheetahs, zebras, and yaks, for example—disappeared from the continent.

Today groups of people in scattered parts of the world, from the Arctic to Central Africa, still follow the hunter-gatherer way of life to some degree. These people, such as the hunter shown in **Figure 6–3**, make relatively few demands on the environment. However, most of them use some form of technology, such as guns, snowmobiles, or manufactured tools.

✓ CHECKPOINT *What are ecosystem goods and services?*

Agriculture

During thousands of years of searching for food, early hunter-gatherers learned how plants grew and ripened. They also discovered which ones were useful for food and medicines. By the end of the last ice age—about 11,000 years ago—humans began the practice of farming, or **agriculture.** Soon, people in different regions of the world were growing wheat, rice, and potatoes. The development of agriculture also included raising animals, such as sheep, goats, cows, pigs, and horses.

The spread of agriculture was among the most important developments in human history. Why? Because agriculture provides human societies with a fundamental need: a dependable supply of food that can be produced in large quantity and stored for later use. With a stable and predictable food supply, humans began to gather in larger settlements rather than travel in search of food. Stable communities, including towns and cities, enabled the development of the elements of civilization, such as government, laws, and writing.

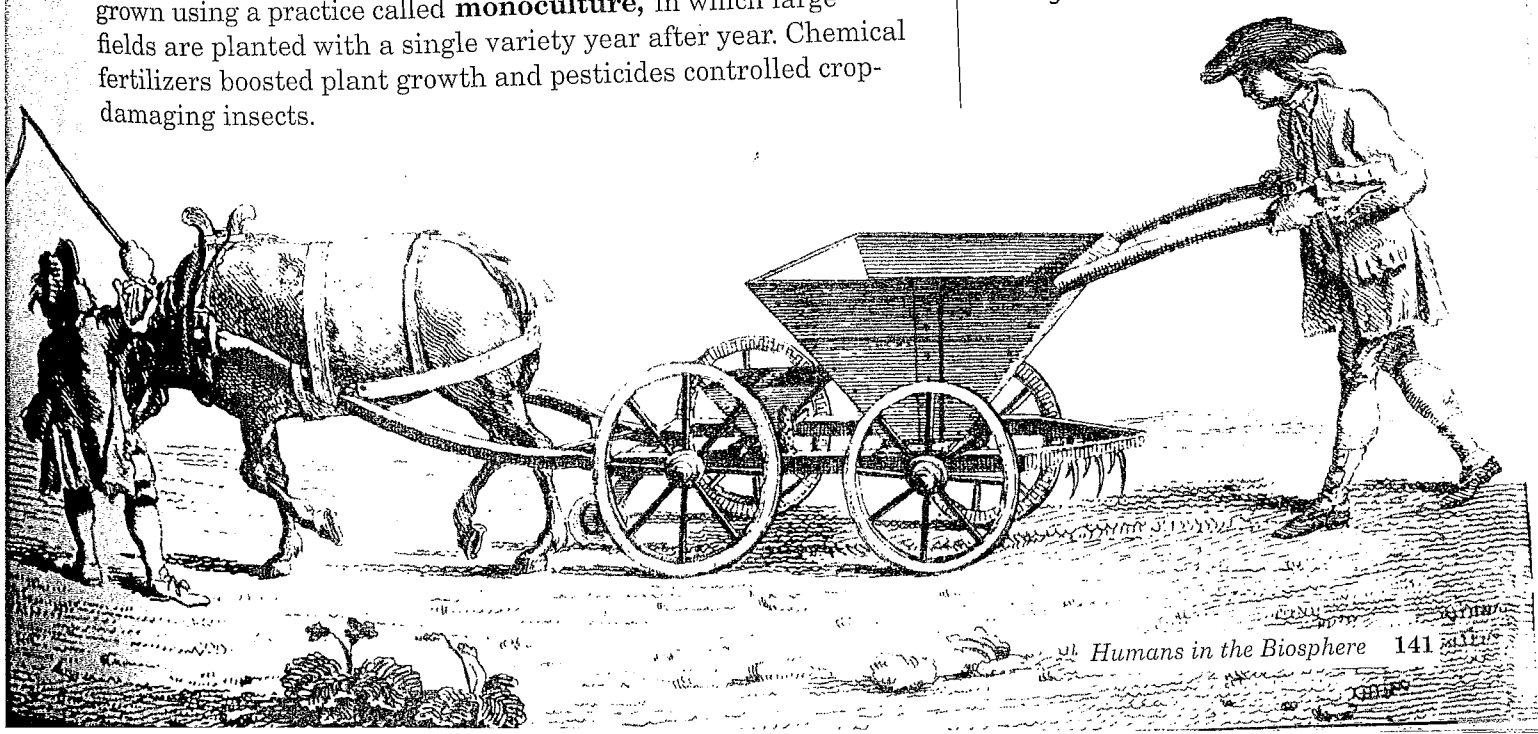
From Traditional to Modern Agriculture Farming continued to develop for thousands of years. Farmers gradually acquired machinery, such as plows and the seed drill shown in **Figure 6–4,** to help with cultivation. World exploration led to an exchange of crops around the globe. For example, Europeans began to grow crops native to North and South America, such as potatoes and squash. Americans and Europeans cultivated rice, which is native to Asia.

In the 1800s and 1900s, advances in science and technology set the stage for a remarkable change in agriculture. Large-scale irrigation in dry areas such as the western United States allowed deserts to become breadbaskets. Machinery for plowing, planting, and harvesting helped farmers increase their yields tremendously. Agricultural scientists developed new varieties of crops that produce higher yields. These new crops were often grown using a practice called **monoculture,** in which large fields are planted with a single variety year after year. Chemical fertilizers boosted plant growth and pesticides controlled crop-damaging insects.

Word Origins

Agriculture is a combination of the Latin words *ager,* meaning "a field," and *cultura,* meaning "care." *Agriculture* is the science and art of farming, which includes the cultivation of field soils, production of crops, and the raising of livestock. **If the prefix *agro-* has the same meaning as *agri-*, what do you think the definition of the noun *agrochemical* is?**

▼ **Figure 6–4** By the 1700s, most Europeans relied on simple tools and animal-drawn plows and vehicles to work the land. This illustration shows a farmer guiding a four-wheeled seed drill as his horse pulls it across a field. The seed drill was invented to help farmers plant seeds in straight lines.
Inferring *Why is planting seeds in straight lines an advantage?*



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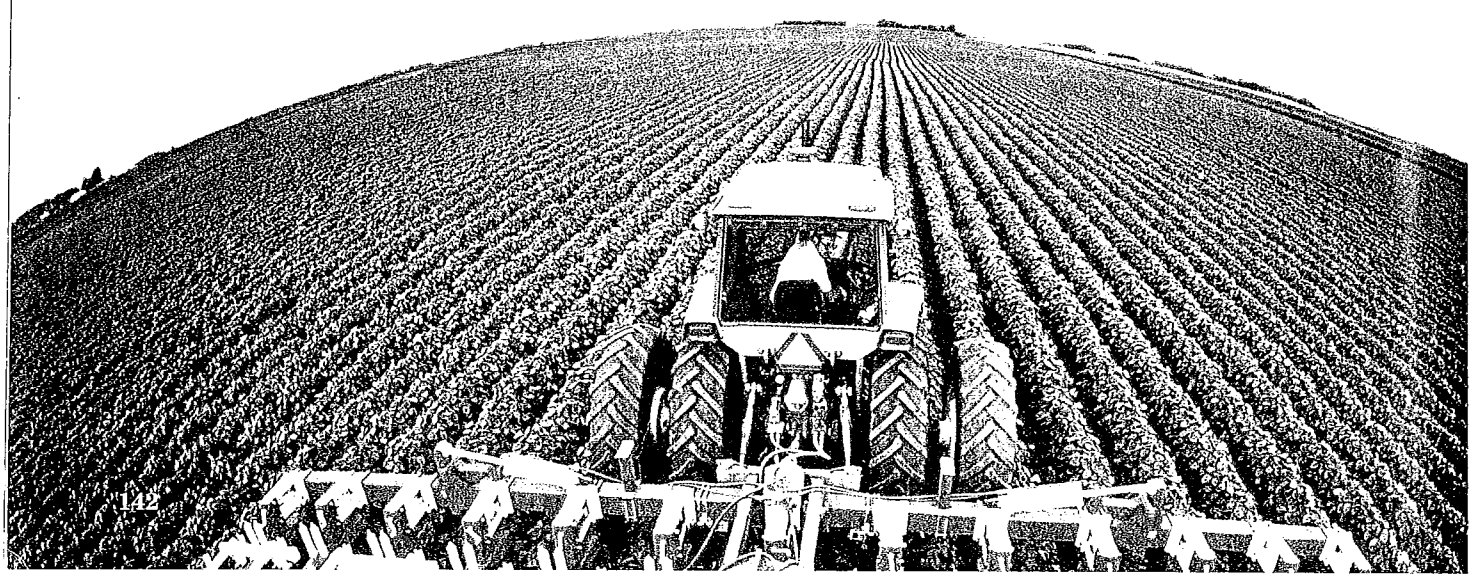
The Green Revolution By the middle of the twentieth century, despite agricultural advances, there were food shortages in many parts of the world. Governments and scientists began a major effort to increase food production in those countries. Plant breeders developed highly productive "miracle strains" of wheat and rice. Modern agricultural techniques were introduced, such as monoculture and the use of chemical fertilizers. This effort came to be called the **green revolution,** because it greatly increased the world's food supply.

The benefits of the green revolution have been enormous. In 20 years, Mexican farmers increased their wheat production 10 times. India and China, countries with the world's largest populations, produced enough food to feed their own people for the first time in years. Over the last 50 years, the green revolution has helped world food production double. Even though hunger is still a major problem in parts of the world, the green revolution has provided many people with better nutrition.

Challenges for the Future While increasing world food supplies, modern agriculture has created ecological challenges. For example, large-scale monoculture can lead to problems with insect pests and diseases. To a corn-eating insect, enormous fields of corn look like huge dinner tables, filled with tasty treats! When an insect population is surrounded by food, the population can grow rapidly. When populations of insect pests increase, farmers may increase their use of pesticides. Unfortunately, chemical pesticides can damage beneficial insects, contaminate water supplies, and accumulate in the environment.

A second challenge is finding enough water for irrigation. Less than a quarter of American farmland relies heavily on irrigation, but that land produces a major portion of our harvest. Several states in the West and Midwest, for example, depend heavily on an underground water deposit called the Ogallala aquifer for their water needs. However, evidence indicates that the Ogallala may run dry within 20 to 40 years.

Most ecologists conclude that humanity faces a challenge. We need to maintain the benefits of modern agriculture while developing new approaches to protect natural resources.



▼ **Figure 6–5** This farmer is using a tractor to cultivate a field of soybeans. Modern agricultural machinery such as this has helped increase crop yields. **Applying Concepts** *What is the name for the practice of planting large fields with a single crop?*

Industrial Growth and Urban Development

Human society and its impact on the biosphere were transformed by the Industrial Revolution, which added machines and factories to civilization during the 1800s. That revolution led to the combination of industrial productivity and scientific know-how that provides us with most of the conveniences of modern life, from the homes we live in and the clothes we wear to the electronic devices we use in work and play. Mass-produced farm machinery makes efficient, large-scale agriculture possible. Automobiles give us mobility. Of course, to produce and power these machines, we need energy. We obtain most of this energy from fossil fuels—coal, oil, and natural gas.

For many years, cities and industries discarded wastes from manufacturing, energy production, and other sources into the air, water, and soil. Meanwhile, as urban centers became crowded, many people moved from the cities to the suburbs. The result of this movement was the growth of suburbs and the spread of suburban communities across the American landscape, as shown in **Figure 6–6.** Industrial development and the growth of cities and suburbs are closely tied to the high standard of living that so many people enjoy.

Many ecologists, however, are concerned about the effects of human activity on both local and global environments. Certain kinds of industrial processes pollute air, water, and soil. Dense human communities produce wastes that must be disposed of. Suburban growth consumes farmland and natural habitats, and can place additional stress on plant and animal populations and on the biosphere's life-support systems. Can we learn to control these harmful effects of human activity while preserving—or even improving—our standard of living? This is the enormous challenge that you and your children will face.

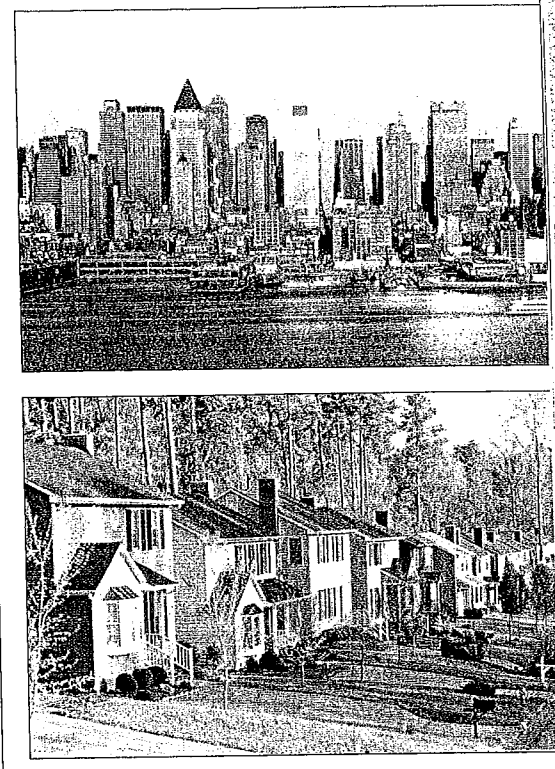


Figure 6–6 In the United States today, most people live and work either in cities or in the suburbs that surround them. **Problem Solving** *List some ways that problems associated with the growth of cities and suburbs can be prevented.*

6–1 Section Assessment

1. **Key Concept** List three types of human activities that can affect the biosphere. For each activity, give one environmental cost and one benefit.
2. Identify three of Earth's resources on which humans and other organisms depend for the long-term survival of their species.
3. What did agriculture provide that changed the course of human history?
4. Identify two ways in which the Industrial Revolution has affected living things.
5. **Critical Thinking Predicting** How might improved agricultural practices in a developing nation affect that nation's human population?

You & Your Community

Mapping Community Growth

Are there signs of growth in your community, or in some other community you know? Map out some of the residential areas, shopping malls, and industrial parks in the community. Then, write a brief paragraph telling how this growth might impact local ecosystems.

6–2 Renewable and Nonrenewable Resources

Guide for Reading

Key Concepts

- How are environmental resources classified?
- What effects do human activities have on natural resources?

Vocabulary

renewable resource
nonrenewable resource
sustainable development
soil erosion • desertification
deforestation • aquaculture
smog • pollutant • acid rain

Reading Strategy: Building Vocabulary

As you read, make notes about the meaning of each new term in the list above. Then, draw a concept map to show the relationships among the terms in this section.

A few hundred years ago, inhabitants of English villages could graze their cattle on shared pasture land called commons. Since grazing was free of charge, villagers often put as many cattle as possible on those commons. Occasionally there were more cattle on the commons than the land could support. Even as the land became overused, people kept putting more animals on it. After all, those who didn't use that free land would sacrifice their own profit while others would continue to benefit. Overgrazing on village commons sometimes caused the pastures to deteriorate so badly that they could no longer support cattle.

Today, environmentalists often talk about the *tragedy of the commons.* This phrase expresses the idea that any resource, such as water in the ground or fish in the sea, that is free and accessible to everyone, may eventually be destroyed. Why? Because if no one is responsible for protecting a resource, and if no one benefits from preserving it, people will use it up. If humans do not preserve the goods and services of an ecosystem, these resources may suffer the same fate as the common grazing lands in English villages.

Classifying Resources

Environmental goods and services may be classified as either renewable or nonrenewable. A tree is an example of a renewable resource, because a new tree can grow in place of an old tree that dies or is cut down. **Renewable resources** can regenerate if they are alive or can be replenished by biochemical cycles if they are nonliving. However, a renewable resource is not necessarily unlimited. Fresh water, for example, is a renewable resource that can easily become limited by drought or overuse.

A **nonrenewable resource** is one that cannot be replenished by natural processes. The fossil fuels coal, oil, and natural gas are nonrenewable resources. Fossil fuels formed over hundreds of millions of years from deeply buried organic materials. When these fuels are depleted, they are gone forever.

The classification of a resource as renewable or nonrenewable depends on its context. Although a single tree is renewable, a population of trees in a forest ecosystem—on which a community of organisms depends—may not be renewable, because that ecosystem may change forever once those trees are gone.

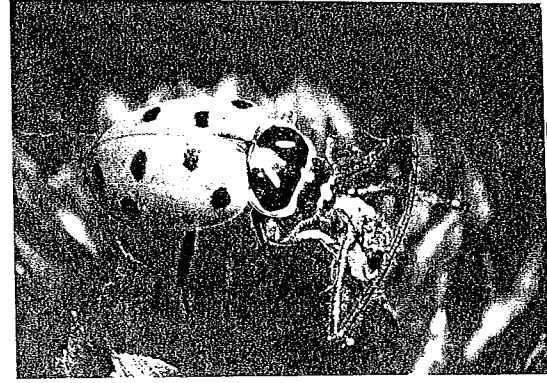
CHECKPOINT *What is the "tragedy of the commons"?*

Figure 6–7 Natural resources can be classified as renewable or nonrenewable. The grass growing in these pastures is a renewable resource—as long as the number of sheep grazing there is limited.

Sustainable Development

How can we provide for our needs while maintaining ecosystem goods and services that are renewable? The concept of sustainable development is one answer to this major question. **Sustainable development** is a way of using natural resources without depleting them and of providing for human needs without causing long-term environmental harm.

Human activities can affect the quality and supply of renewable resources such as land, forests, fisheries, air, and fresh water. Ecological research can help us understand how human activities affect the functioning of ecosystems. To work well, sustainable development must take into account both the functioning of ecosystems and the ways that human economic systems operate. Sustainable strategies must enable people to live comfortably and improve their situation. The use of insects to control insect pests, as shown in **Figure 6–8**, is one such strategy. In finding sustainable-development strategies, ecological research can have a practical, positive impact on the environment we create for ourselves and future generations.



▲ **Figure 6–8** This ladybug is eating an insect pest—a black aphid. New strategies for pest control that employ beneficial insects may help farmers reduce the use of pesticides. **Inferring** *How does biological pest control contribute to sustainable development?*

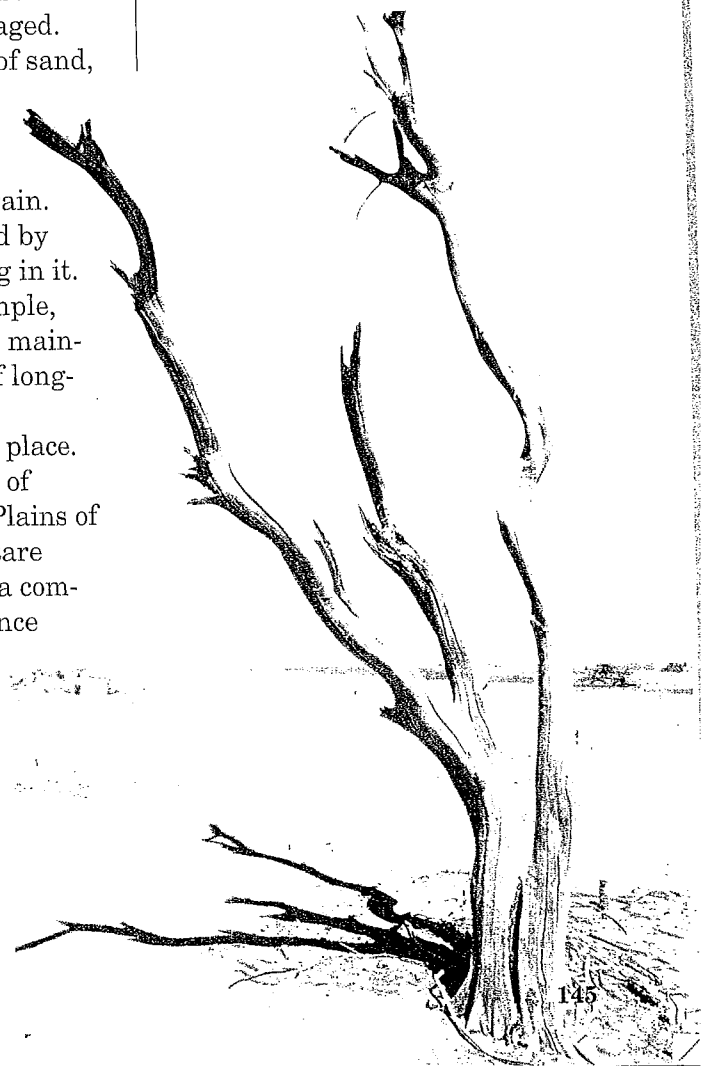
Land Resources

Land is a resource that provides space for human communities and raw materials for industry. Land also includes the soils in which crops are grown. If managed properly, soil is a renewable resource. Soil, however, can be permanently damaged if it is mismanaged.

Food crops grow best in fertile soil, which is a mixture of sand, clay, rock particles, and humus (material from decayed organisms). Most of the humus that makes soil fertile is in the uppermost layer of the soil, called topsoil. Good topsoil absorbs and retains moisture yet allows excess water to drain. It is rich in nutrients but low in salts. Such soil is produced by long-term interactions between the soil and plants growing in it. Much agricultural land in the American Midwest, for example, was once covered by prairie ecosystems that produced and maintained a meter or more of very fertile topsoil. Deep roots of long-lived grasses held soil in place against rain and wind.

Plowing the land removes the roots that hold the soil in place. This increases the rate of **soil erosion**—the wearing away of surface soil by water and wind. A typical field on the High Plains of the Midwest loses roughly 47 metric tons of topsoil per hectare every year! In certain parts of the world with dry climates, a combination of farming, overgrazing, and drought has turned once productive areas into deserts, as shown in **Figure 6–9**. This process is called **desertification.** There are, however, a variety of sustainable-development practices that can guard against these problems. One practice is contour plowing, in which fields are plowed across the slope of the land to reduce erosion. Other strategies include leaving the stems and roots of the previous year's crop in place to help hold the soil and planting a field with rye rather than leaving it unprotected from erosion.

▼ **Figure 6–9** **Human activities affect the supply and the quality of renewable resources.** In dry regions, human activities, such as farming practices that fail to protect the soil, can contribute to desertification.



Forest Resources

Earth's forests are an important resource for the products they provide and for the ecological functions they perform. People use the wood from forests to make products ranging from homes to paper. In many parts of the world, wood is still burned as fuel for cooking and heating. But living forests also provide a number of important ecological services. Forests have been called "lungs of the Earth" because they remove carbon dioxide and produce oxygen. Forests also store nutrients, provide habitats and food for organisms, moderate climate, limit soil erosion, and protect freshwater supplies.

Whether a forest can be considered a renewable resource depends partly on the type of forest. For example, the temperate forests of the northeastern United States can be considered renewable. Most of these forests have been logged at least once in the past and have grown back naturally. However, today's forests differ somewhat in species composition from the forests they replaced.

Other forests, such as those in Alaska and the Pacific Northwest, are called old-growth forests because they have never before been cut. Worldwide, about half of the area originally covered by forests and woodlands has been cleared. Because it takes many centuries to produce old-growth forests, they are in effect nonrenewable resources. Old-growth forests often contain a rich variety of species. When logging occurs in these forests, the species they contain may be lost.

▼ **Figure 6–10** Planting new trees is one way to counteract the effects of deforestation. **Applying Concepts** *What are two ways in which reforestation might affect the biosphere?*

Deforestation Loss of forests, or **deforestation,** has several effects. Deforestation can lead to severe erosion as soil is exposed to heavy rains. Erosion can wash away nutrients in the topsoil. Grazing or plowing after deforestation can cause permanent changes to local soils and microclimates that in turn prevent the regrowth of trees.

Forest Management There are a variety of sustainable-development strategies for forest management. In some forests, mature trees can be harvested selectively to promote the growth of younger trees and preserve the forest ecosystem. In areas where forests have already been cut, foresters today often plant, manage, harvest, and replant tree farms, as shown in **Figure 6–10.** Tree farms can now be planted and harvested efficiently, making them fully renewable resources. Tree geneticists are also breeding new, faster-growing tree varieties that produce high-quality wood.

CHECKPOINT *What is deforestation?*

Fishery Resources

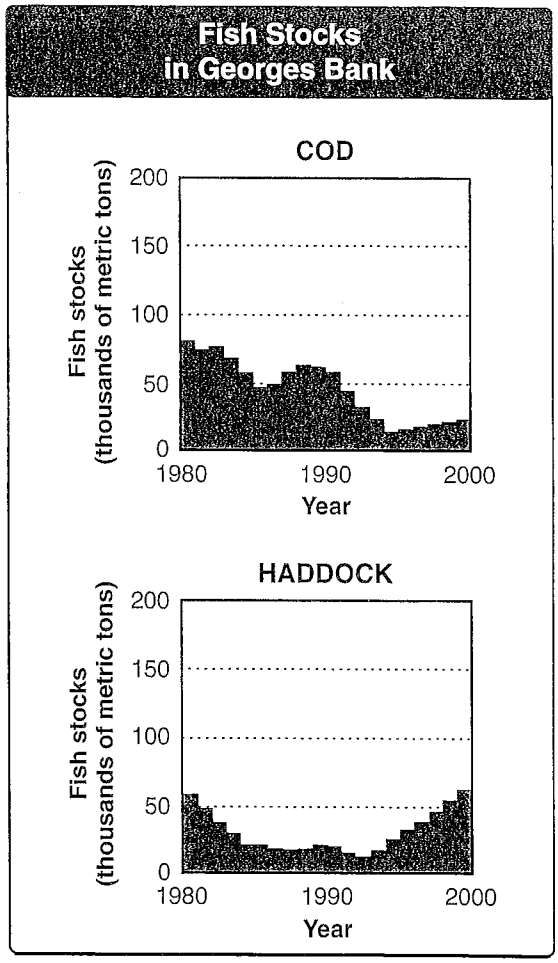
Fishes and other animals that live in water are a valuable source of food for humanity. For example, consider the food provided by the Chesapeake Bay and its watershed, which includes the saltwater bay itself and the freshwater rivers and streams that flow into it. This complex ecosystem supplies people with fishes such as striped bass and American shad, and shellfishes such as crabs and oysters. The recent history of fisheries, or fishing grounds, is an example of the tragedy of the commons. Fortunately, it also shows how ecological research can help people begin to correct an environmental problem.

Overfishing Overfishing, or harvesting fish faster than they can be replaced by reproduction, greatly reduced the amount of fish in parts of the world's oceans. Between 1950 and 1990, the world fish catch grew from 19 million tons to more than 90 million tons. The fish that were caught helped feed the world's people. But as the catch increased, the populations of some fish species began to shrink. By the early 1990s, populations of cod and haddock had dropped so low that researchers feared these fishes might disappear from the sea.

The declining fish populations are an example of the tragedy of the commons. People from several countries were taking advantage of a resource—fisheries—but no one took responsibility for maintaining that resource. Until fairly recently, fisheries seemed to be a renewable resource, one that could be harvested indefinitely. But overfishing threatened to destroy what was once a renewable resource.

Sustainable Development Is there a way to manage fisheries sustainably? That's where ecological research has entered the picture. Fishery ecologists gathered data on the size of fish populations and their growth rate. The U.S. National Marine Fisheries Service used these data to create guidelines for United States commercial fishing. The guidelines specified how many fish, and of what size, could be caught in various parts of the oceans. The regulations are helping fish populations recover, as shown in **Figure 6–11.** The regulations caused loss of jobs in the short term, but are designed to protect the fishing industry for the future.

Aquaculture The raising of aquatic animals for human consumption, which is called **aquaculture,** is also helping to sustain fish resources. If not properly managed, aquaculture can pollute water and damage aquatic ecosystems. However, environment-friendly aquaculture techniques are being developed.



▲ **Figure 6–11** These graphs show how two fish populations—cod and haddock—have fluctuated in Georges Bank, a fishery off the New England coast. The fish populations began to rise after regulations restricted commercial fishing. **Interpreting Graphics** *Describe the history of the cod population in Georges Bank between 1980 and 2000.*

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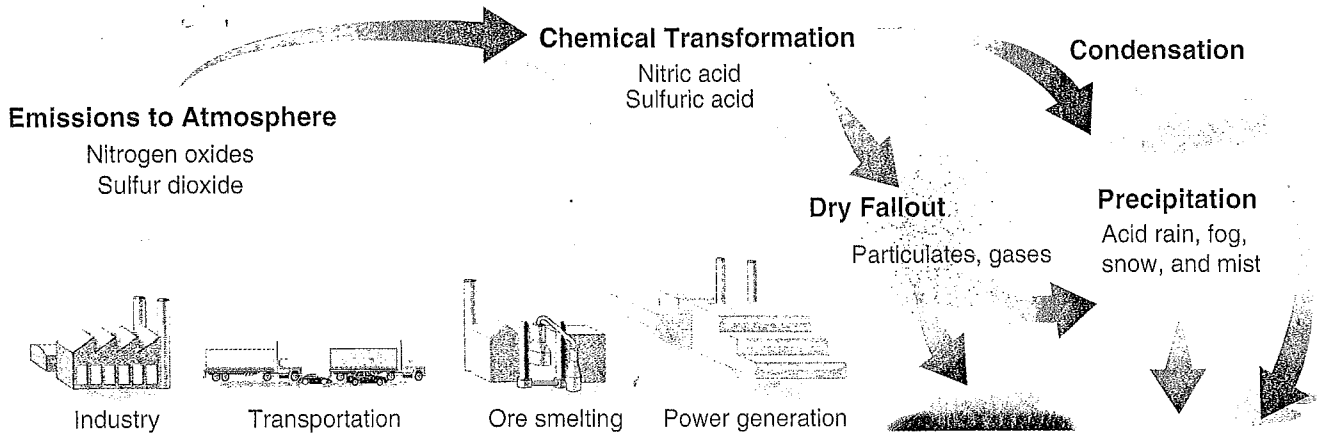


Figure 6–12 Acid rain results from the chemical transformation of nitrogen and sulfur products that come from human activities. The face of the statue (below) shows damage from acid rain. **Interpreting Graphics** *What pathways do the chemicals in atmospheric emissions take on their way to becoming acid rain?*

Air Resources

Air is a common resource that we use every time we breathe. The condition of the air affects people's health. The preservation of air quality remains a challenge for modern society.

If you live in a large city, you have probably seen **smog,** a mixture of chemicals that occurs as a gray-brown haze in the atmosphere. Smog is primarily due to automobile exhausts and industrial emissions. Because it threatens the health of people with asthma and other respiratory conditions, smog is considered a pollutant. A **pollutant** is a harmful material that can enter the biosphere through the land, air, or water.

The burning of fossil fuels can release pollutants that cause smog and other problems in the atmosphere. Potentially toxic chemicals, like nitrates, sulfates, and particulates (pahr-TIK-yoo-lits), are especially troublesome in large concentrations. Particulates are microscopic particles of ash and dust that can enter the nose, mouth, and lungs, causing health problems over the long term. Today, most industries use technology to control emissions from factory smokestacks. Strict automobile emission standards and clean-air regulations have improved air quality in many American cities, but air pollution is an ongoing problem in other parts of the world.

Many combustion processes, such as the burning of fossil fuels, release nitrogen and sulfur compounds into the atmosphere. When these compounds combine with water vapor in the air, they form drops of nitric and sulfuric acids. These strong acids can drift for many kilometers before they fall as **acid rain.** Acid rain can kill plants by damaging their leaves and changing the chemistry of soils and standing-water ecosystems. Acid rain may also dissolve and release toxic elements, such as mercury, from the soil, freeing those elements to enter other portions of the biosphere. **Figure 6–12** shows the processes that lead to the formation of acid rain.

✓CHECKPOINT *What is a pollutant?*

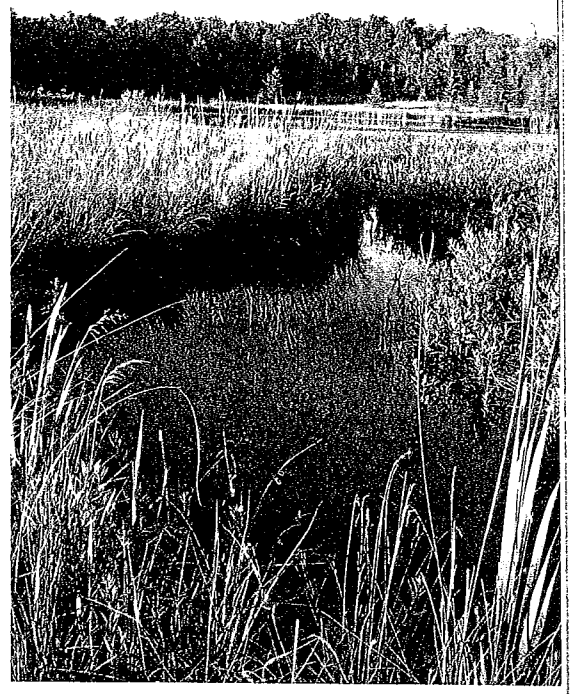
Freshwater Resources

Americans use billions of liters of fresh water daily for everything from drinking and washing to watering crops and making steel. Although water is a renewable resource, the total supply of fresh water is limited. For this reason, protecting water supplies from pollution and managing society's ever-growing demand for water are major priorities.

Pollution threatens water supplies in several ways. Improperly discarded chemicals can enter streams and rivers. Wastes discarded on land can seep through soil and enter underground water supplies that we tap with wells. Domestic sewage, which is the wastewater from sinks and toilets, contains nitrogen and phosphorous compounds that can encourage the growth of algae and bacteria in aquatic habitats. Sewage can also contain microorganisms that can spread disease among humans and animals. In this country, most cities and towns now treat their sewage in order to make it safer.

One way of ensuring the sustainable use of water resources is to protect the natural systems involved in the water cycle. For example, wetlands such as the one shown in **Figure 6–13** can help to purify the water passing through them. As water flows slowly through a swamp, densely growing plants filter certain pollutants out of the water. Similarly, forests and other vegetation help to purify the water that seeps into the ground or runs off into rivers and lakes.

As demand for water grows rapidly in many parts of the United States, water conservation is becoming an increasingly important aspect of sustainable development. There are many strategies for conserving water—in homes, industry, and agriculture. More than three-quarters of all water consumed in this country is used in agriculture, so conservation in this area can save large amounts of water. For example, drip irrigation delivers water directly to plant roots. This reduces the amount of water lost through evaporation.



▲ **Figure 6–13** Wetlands provide a valuable ecosystem service by filtering certain pollutants from the water. **Applying Concepts** *How does this filtering process happen?*

6–2 Section Assessment

1. **Key Concept** What is the difference between a renewable and a nonrenewable resource?
2. **Key Concept** List two human activities that affect land resources, and explain the changes that can result. Do the same for air and water resources.
3. How does the decline in world fisheries represent a "tragedy of the commons"?
4. Identify two ways in which environmental resources are important to human health.
5. **Critical Thinking Applying Concepts** Describe sustainable development strategies to manage forests as a renewable resource.

Writing in Science

Cause-Effect Paragraph

Write a paragraph explaining the effect of fishing restrictions on fish populations. Your paragraph should explain why the regulations were needed as well as the effect of the regulations.

6-3 Biodiversity

Guide for Reading

Key Concepts

- Why is biodiversity important?
- What are the current threats to biodiversity?
- What is the goal of conservation biology?

Vocabulary

biodiversity
ecosystem diversity
species diversity
genetic diversity
extinction
endangered species
habitat fragmentation
biological magnification
invasive species
conservation

Reading Strategy: Asking Questions Before you read, rewrite the headings in the section as *how, why,* or *what* questions about biodiversity. As you read, write brief answers to your questions.

Those of us who love nature find much to admire in the many forms of life that surround us. We marvel at the soaring flight of an eagle, the majestic movements of a whale, and the colors of spring wildflowers. "Variety," the saying goes, "is the spice of life." But variety in the biosphere gives us more than just interesting things to look at. Human society takes part in local and global food webs and energy cycles, and depends on both the physical and biological life-support systems of our planet. For that reason, our well-being is closely tied to the well-being of a great variety of other organisms—including many that are neither majestic nor beautiful to our eyes.

The Value of Biodiversity

Another word for variety is diversity. Therefore, biological diversity, or **biodiversity,** is the sum total of the genetically based variety of all organisms in the biosphere. **Ecosystem diversity** includes the variety of habitats, communities, and ecological processes in the living world. **Species diversity** refers to the number of different species in the biosphere. So far, biologists have identified and named about 1.5 million species and estimate that millions more may be discovered in the future. **Genetic diversity** refers to the sum total of all the different forms of genetic information carried by all organisms living on Earth today. Within each species, genetic diversity refers to the total of all different forms of genes present in that species. You will read about genetic information later in the book.

Biodiversity is one of Earth's greatest natural resources. Species of many kinds have provided us with foods, industrial products, and medicines—including painkillers, antibiotics, heart drugs, antidepressants, and anticancer drugs. For example, the rosy periwinkle plant in **Figure 6-14** is the source of substances used to treat certain cancers. The biodiversity represented by wild plants and animals is a kind of "library" of genetic information upon which humans can draw for future use. For example, most crop plants have wild relatives with useful traits such as resistance to disease or pests. When biodiversity is lost, potential sources of material with significant value to the biosphere and to humankind may be lost with it.

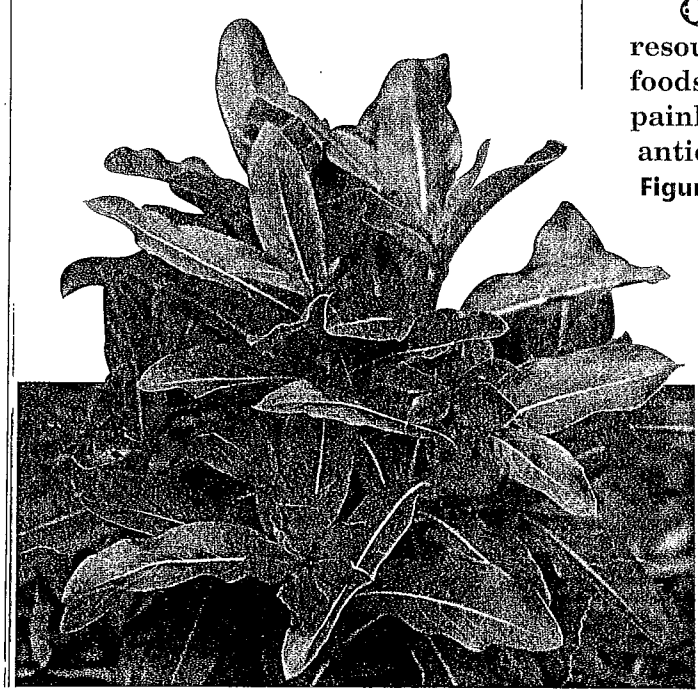


Figure 6-14 Biodiversity is one of Earth's greatest natural resources. Species of many kinds have provided us with foods, industrial products, and medicines. The rosy periwinkle is a pink-petaled flowering plant native only to Madagascar. Drugs derived from this plant, such as vincristine, are used to treat certain cancers, including leukemia.

Threats to Biodiversity

Human activity can reduce biodiversity by altering habitats, hunting species to extinction, introducing toxic compounds into food webs, and introducing foreign species to new environments. As human activities alter ecosystems, this may lead to the extinction of species. **Extinction** occurs when a species disappears from all or part of its range. A species whose population size is declining in a way that places it in danger of extinction is called an **endangered species.** As the population of an endangered species declines, the species loses genetic diversity—an effect that can make it even more vulnerable to extinction.

Habitat Alteration

When land is developed, natural habitats may be destroyed. Habitats supply organisms' needs, and they are a limited resource. The animals who live in these habitats, such as the coyote in **Figure 6–15**, must learn new behaviors in order to survive in these new environments. Species' long-term survival depends on the preservation of this limited resource.

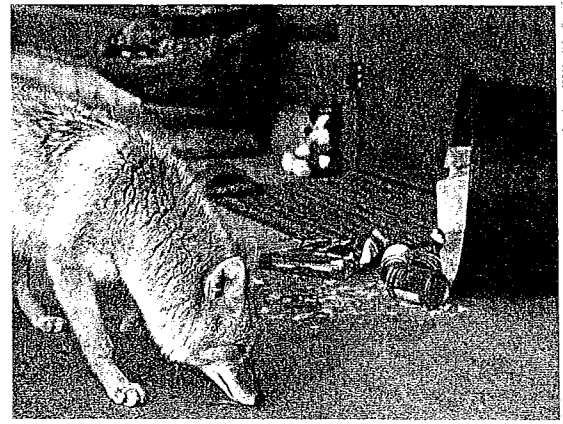
As habitats disappear, the species that live in those habitats vanish. In addition, development often splits ecosystems into pieces, a process called **habitat fragmentation.** As a result, remaining pieces of habitat become biological "islands." We usually think of islands as bits of land surrounded by water. But a biological island can be any patch of habitat surrounded by a different habitat. New York's Central Park is an island of trees and grass in a sea of concrete. In suburbs, patches of forest can be surrounded by farms, houses, and shopping malls. Habitat islands are very different from large, continuous ecosystems. The smaller the "island," the fewer species can live there, the smaller their populations can be, and the more vulnerable they are to further disturbance or climate change.

CHECKPOINT *What is habitat fragmentation?*

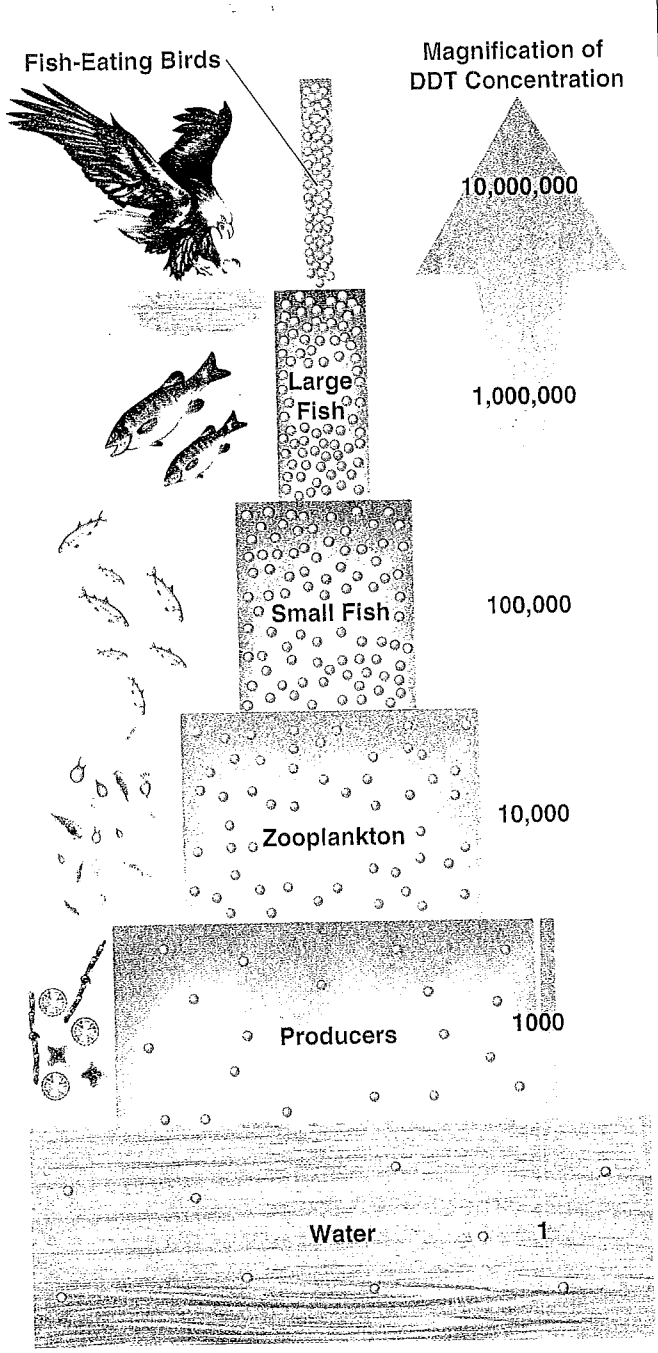
Demand for Wildlife Products

Throughout history, humans have pushed some animal species to extinction by hunting them for food or other products. In the 1800s, hunting caused the extinction of species such as the Carolina parakeet and the passenger pigeon.

Today, in the United States, endangered species are protected from hunting. Hunting, however, still threatens rare animals in parts of Africa, South America, and Southeast Asia. Some species are hunted for meat, fur, or hides. Others are hunted because people think that their body parts such as horns have medicinal properties. The Convention on International Trade in Endangered Species, CITES, bans international trade in products derived from a list of endangered species. Unfortunately, it is difficult to enforce laws in remote wilderness areas.



▲ **Figure 6–15** Human activity can reduce biodiversity by altering habitats. Normally this coyote would be hunting for small prey, but due to a changing habitat, it has learned to make an easy meal from garbage cans.



▲ **Figure 6–16** In the process of biological magnification, the concentration of a pollutant such as DDT—represented here by orange dots—is multiplied as it passes up the food chain from producers to consumers. By the time it reaches the top-level consumers, shown here as fish-eating birds, the amount of DDT in biological tissues can be magnified nearly 10 million times. **Calculating** *By what number is the concentration of DDT multiplied at each successive trophic level?*

Pollution

Many forms of pollution can threaten biodiversity, but one of the most serious problems occurs when toxic compounds accumulate in the tissues of organisms. The history of DDT, one of the first widely used pesticides, explains the situation well. At first, DDT seemed to be a perfect pesticide. It is cheap, remains active for a long time, kills many different insects, and can control agricultural pests and disease-carrying mosquitoes.

When DDT was sprayed, it drained into rivers and streams at low concentrations that seemed harmless. But DDT has two properties that make it hazardous. First, DDT is nonbiodegradable, which means that it is not broken down by metabolic processes in bacteria, plants, or animals. Second, when DDT is picked up by organisms, they do not eliminate it from their bodies. When aquatic plants pick up DDT from water, the pesticide is stored in their tissues. When herbivores eat those plants, they too store DDT. Because an herbivore eats many plants during its life, the DDT can become concentrated to levels ten times higher than levels found in the plants! When carnivores eat herbivores, the toxic substance is concentrated further, as shown in **Figure 6–16.** In this process, called **biological magnification,** concentrations of a harmful substance increase in organisms at higher trophic levels in a food chain or food web. Biological magnification affects the entire food web, although top-level carnivores are at highest risk.

In 1962, biologist Rachel Carson wrote a book called *Silent Spring* that alerted people to the dangers of biological magnification. The widespread spraying of DDT over many years had threatened populations of many animals—especially fish-eating birds like the osprey, brown pelican, and bald eagle—with extinction. One effect of DDT was to make eggs of these birds so fragile that the eggs could not survive intact. By the early 1970s, DDT was banned in the United States and in most other industrialized countries. In the years since, scientists have noted a marked recovery in the populations of birds that had been affected. Bald eagles, for example, can once again be seen around rivers, lakes, and estuaries in the lower 48 states.

✓CHECKPOINT *What is biological magnification?*

Quick Lab

How does biological magnification occur?

Materials paper cups (3 small, 1 medium, and 1 large); 1-L beaker; sand; 12 beads; masking tape

Procedure

1. Use a pencil to punch five holes in the bottom of each paper cup. Place tape over the outsides of the holes. The small cups represent grasshoppers, the medium-sized cup represents an insect-eating lizard, and the large cup represents a hawk.
2. Half-fill each small cup with sand and 4 beads. The sand represents food. The beads represent a chlorinated pesticide.
3. Hold each small cup over a beaker to catch the sand and remove the tape. The sand that flows out of the cup represents digested food. Record the number of beads in each cup.
4. To model the effects of biological magnification on the lizard, empty the contents of the three small cups into the medium-sized cup. Repeat step 3 with the medium-sized cup.
5. Empty your medium-sized cup and those of two classmates into a large cup to model a hawk eating the lizard. Repeat step 3 with the large cup.

Analyze and Conclude

1. **Inferring** Which animals accumulated the most pesticide?
2. **Predicting** Which level of the food chain is most affected by biological magnification?

Introduced Species

One of the most important threats to biodiversity today comes from an unexpected source: apparently harmless plants and animals that humans transport around the world either accidentally or intentionally. Introduced into new habitats, these organisms often become **invasive species** that reproduce rapidly. Invasive species increase their populations because their new habitat lacks the parasites and predators that control their population "back home."

Hundreds of invasive species, including the one in **Figure 6–17**, are already causing ecological problems in the United States. Zebra mussels, an aquatic pest, came on ships from Europe during the 1980s. They spread through the Great Lakes and several major rivers. These mussels reproduce and grow so quickly that they cause major ecological changes and are driving several native species close to extinction. There are also many examples on land. One European weed, the leafy spurge, now infests millions of hectares of grasslands across the Northern Great Plains, where it displaces native plants.

▶ **Figure 6–17** **Human activity can reduce biodiversity by introducing foreign species to new environments.** Native to South America, nutrias have become pests in coastal areas of the southeastern United States. These furry rodents eat water plants that protect fragile shorelines from erosion. This destroys the habitats of species native to those ecosystems.

Conserving Biodiversity

Most people would like to preserve Earth's biodiversity for future generations. In ecology, the term **conservation** is used to describe the wise management of natural resources, including the preservation of habitats and wildlife. The modern science of conservation biology seeks to protect biodiversity. To do so requires detailed information about ecological relationships—such as the way natural populations use their habitats—and integrates information from other scientific disciplines, such as genetics, geography, and natural resource management.

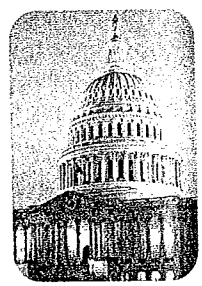
Strategies for Conservation Many conservation efforts are aimed at managing individual species to keep them from becoming extinct. Some zoos, for example, have established captive breeding programs, in which young animals are raised in protected surroundings until the population is stable, then are later returned to the wild. This strategy has succeeded with a few species, including the black-footed ferret.

Today, conservation efforts focus on protecting entire ecosystems as well as single species. Protecting an ecosystem will ensure that the natural habitats and the interactions of many different species are preserved at the same time. This effort is a much bigger challenge. Governments and conservation groups worldwide are working to set aside land, or expand existing areas, as parks and reserves.

Biology and History

Success in Conservation

Human activity can have a dramatic impact on the biosphere, to the point where other forms of life are threatened. Many efforts have been made to protect and preserve Earth's natural environments.



1854
Henry David Thoreau
Thoreau recommends the preservation of wildlife. In his book *Walden,* he cautions against seeking to dominate nature and suggests living in harmony with it.

1872
Yellowstone becomes the world's first national park.

1896
Harriet Hemenway
Hemenway and her cousin, Minna Hall, petition in Boston for legislation to prevent the extinction of birds due to unregulated hunting. By refusing to buy or wear plumed hats, the two cousins are among the first founders of the conservation movement.

1900
Lacey Act
Enacted by the U.S. Congress, the Lacey Act is the first major national conservation law. Transporting illegally killed animals across state borders becomes a federal crime.

1850 1900

The United States has an extensive system of national parks, forests, and other protected areas. Marine sanctuaries are being designated to protect resources such as coral reefs and marine mammals. However, these areas may not be large enough, or contain the right resources, to protect biodiversity.

Protecting species and ecosystem diversity in many places around the world is an enormous challenge. As part of the effort to locate problem areas and set up a list of priorities, conservation biologists often identify biodiversity "hot spots," including those shown in **Figure 6–18** on the following page. Each hot spot is a place where significant numbers of habitats and species are in immediate danger of extinction as a result of human activity. The hot-spot strategy may help scientists and governments to focus their efforts where they are most needed.

Conservation Challenges Protecting resources for the future can require people to change the way they earn their living today. Regulations that restrict fishing, for example, can impose severe financial hardships on fishers for several years. That's why conservation regulations must be informed by solid research, and must try to maximize benefits while minimizing economic costs. But an ecological perspective tells us that if we do not take some difficult steps today, some resources may disappear. If that happens, many jobs that depend on ecosystem goods and services, such as fishing, will be lost permanently.

CHECKPOINT *Why is it important to preserve entire ecosystems?*

Writing in Science

Choose and research a specific endangered species and its habitat. Then, write a proposal that explains the problem and offers one or more possible conservation efforts for that species.

1933
Civilian Conservation Corps
President Roosevelt establishes the CCC, providing work in reforestation, prevention of soil erosion, and park and flood control projects.

1966
Endangered Species Preservation Act
This act allows for the identification of and research on endangered species.

1970
Earth Day
The first celebration takes place in New York to rally against pollution and population overgrowth.

1992
Earth Summit
A United Nations conference in Brazil seeks international solutions for environmental issues, including the worldwide loss of species.

1950 2000

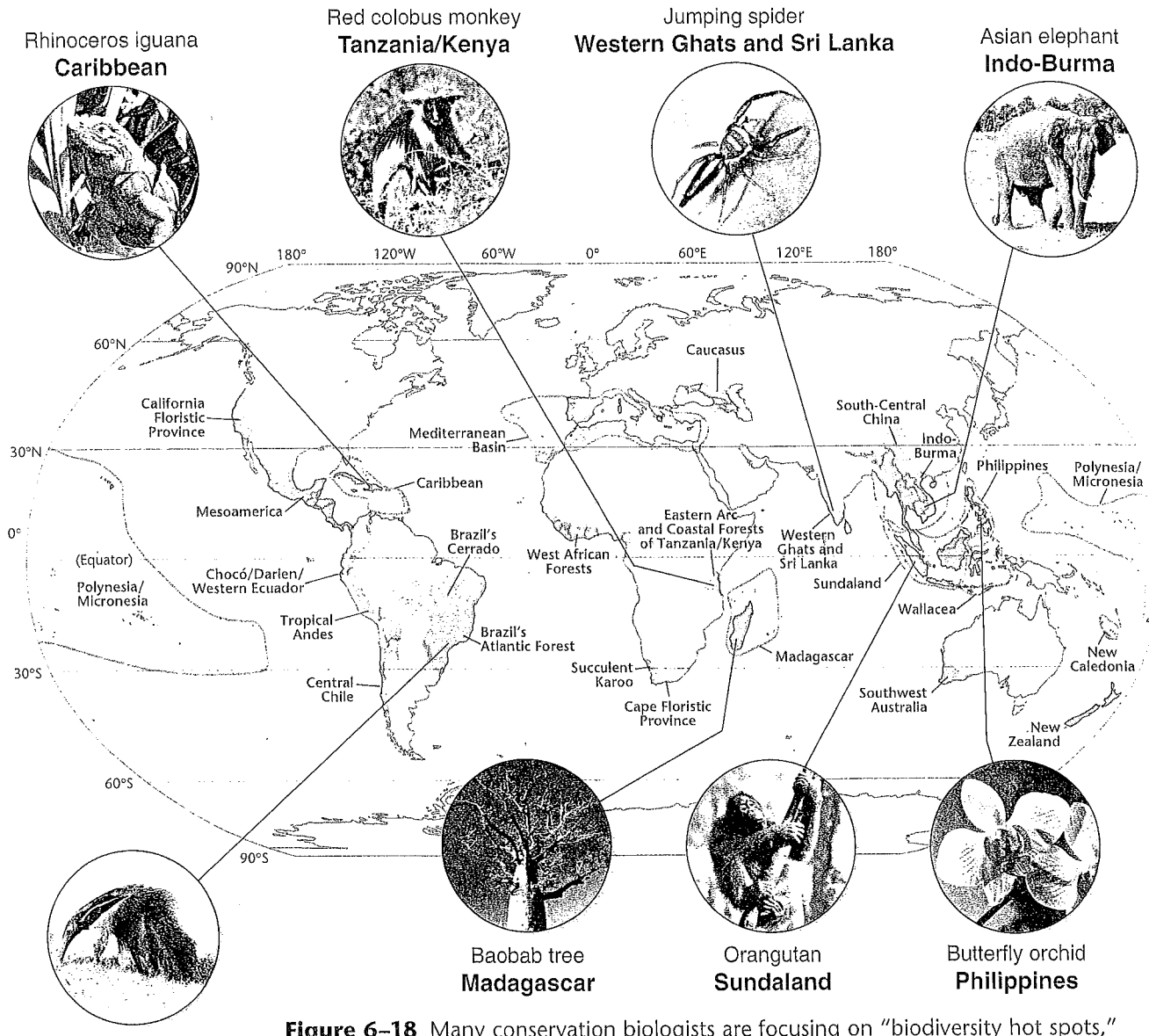


Figure 6–18 Many conservation biologists are focusing on "biodiversity hot spots," where the biodiversity of these unique ecosystems is threatened. The hot spots are shown in orange on the map. **By focusing on protecting specific ecosystems, biologists hope to preserve global biodiversity.**

6–3 Section Assessment

1. **Key Concept** Why is biodiversity worth preserving?
2. **Key Concept** List four activities that can threaten biodiversity.
3. **Key Concept** What is the current focus of conservation biologists worldwide?
4. Explain the relationship between habitat size and species diversity.
5. Why are habitats limited resources? How might their destruction affect the long-term survival of species?
6. **Critical Thinking Predicting** What problems could result if an endangered species were introduced into a nonnative habitat?

Focus on the BIG Idea

Science, Technology, and Society Review biomes in Chapter 4. Then, choose one of the hot spots shown above. Find out about the biome in which these unique ecosystems and endangered species occur. Report on your findings and suggest specific actions that can be taken to preserve the biome's biodiversity.

6–4 Charting a Course for the Future

For most of human history, environmental change was a local affair. For example, many animals in the Hawaiian Islands became extinct after humans arrived there. The effect of these extinctions on the biosphere at large was negligible. Since your parents and grandparents were born, however, global human population has grown from around 2.5 billion to more than 6.1 billion! Today, much of Earth's land surface has been altered by human activity.

In order to plan a sound environmental strategy for the twenty-first century, we need data provided by research. This research requires information from geology, chemistry, physics, and meteorology, as well as ecology. **Researchers are gathering data to monitor and evaluate the effects of human activities on important systems in the biosphere. Two of these systems are the ozone layer high in the atmosphere and the global climate system.** Scientists' investigations of these two systems—and the actions taken as a result—show how research can have a positive impact on the global environment.

Guide for Reading

Key Concept
- What are two types of global change of concern to biologists?

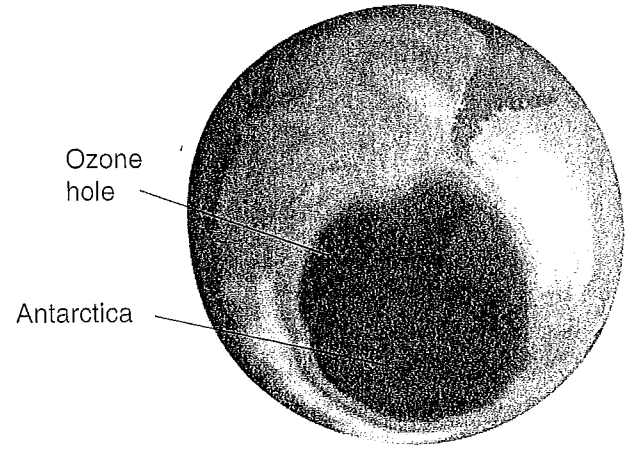
Vocabulary
ozone layer
global warming

Reading Strategy: Summarizing As you read, find the key concept in the section. Write down a few words or phrases from the key concept, then use them in a summary of Section 6–4.

Ozone Depletion

Between 20 and 50 kilometers above Earth's surface, the atmosphere contains a relatively high concentration of ozone gas called the **ozone layer.** Molecules of ozone consist of three oxygen atoms. Although ozone at ground level is a pollutant, the naturally occurring ozone layer serves an important function. It absorbs a good deal of harmful ultraviolet, or UV, radiation from sunlight before it reaches Earth's surface. You may know that overexposure to UV radiation is the principal cause of sunburn. You may not know that exposure to UV can also cause cancer, damage eyes, and decrease organisms' resistance to disease. Intense UV radiation can also damage tissue in plant leaves and even phytoplankton in the oceans. Thus, by shielding the biosphere from UV light, the ozone layer serves as a global sunscreen.

Early Evidence Beginning in the 1970s, scientists found evidence from satellite data that the ozone layer was in trouble. The first problem sign was a gap, or "hole," in the ozone layer over Antarctica during winter. Since it was first discovered, the ozone hole has grown larger and lasted longer. A similar ozone hole also appeared over the Arctic. In 1974, a research team including Mario Molina of the Massachusetts Institute of Technology and F. Sherwood Rowland of the University of California at Irvine published data showing that gases called chlorofluorocarbons, or CFCs, could damage the ozone layer.



▼ **Figure 6–19** **Many biologists are concerned about the thinning of the ozone layer.** This image, taken by satellite in 2001, shows the thinning of the ozone layer in the Southern Hemisphere. The image is color-coded, with yellow being the area with the highest concentration of ozone and blue the lowest. The ozone hole is the bright blue area surrounding Antarctica.

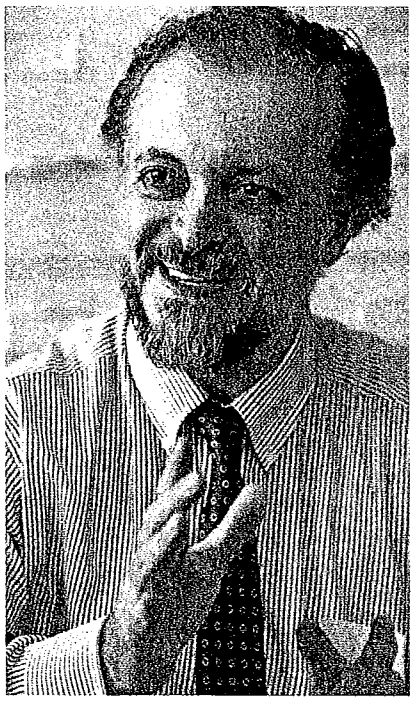


Figure 6–20 Mario Molina (left), F. Sherwood Rowland, and Paul Crutzen shared the Nobel Prize in 1995 for their research on factors that can destroy ozone. **Applying Concepts** *What action did nations take to deal with the ozone hole?*

One Solution CFCs were once widely used as propellants in aerosol cans; as coolant in refrigerators, freezers, and air conditioners; and in the production of plastic foams. Because of the research of Molina, Rowland, and other scientists, the United States and many other nations began reducing the use of CFCs in 1987. Today, most uses of CFCs are banned.

Because CFC molecules can linger for as long as a century, their effects are not yet over. But the level of chlorine from CFCs in the atmosphere has already begun to fall, indicating that the CFC ban will have positive, long-term effects on the global environment. Current data predict that the ozone holes should shrink and disappear within 50 years.

CHECKPOINT *What is ozone depletion?*

Analyzing Data

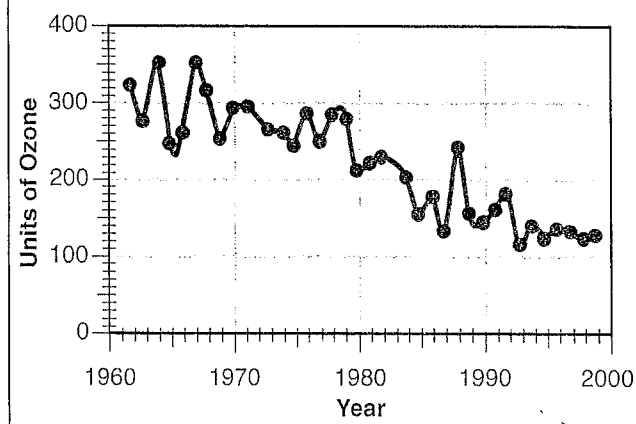
Banning CFCs

A layer of ozone is normally present in Earth's upper atmosphere, or stratosphere. The ozone layer prevents much of the ultraviolet light emitted by the sun from reaching Earth's surface. In the 1970s, scientists noticed that ozone levels in the stratosphere were dropping. Evidence indicated that this was caused by the introduction of chlorofluorocarbons into the atmosphere.

In the lower atmosphere, CFCs are stable. However, when CFCs are carried into the stratosphere, UV rays bombard them and break them apart. This process causes a series of chemical reactions that break down the ozone molecules into ordinary oxygen, which offers no protection from UV light at all.

In 1987, forty-six nations signed an agreement called the Montreal Protocol, which called for an immediate reduction in production and use of CFCs. The following year, the United States passed a law to phase out the use of CFCs in aerosol cans by 2000. The members of the Montreal Protocol met again in 1990 and agreed to end the use of most CFCs by the year 2000. All of these resolutions have taken effect by now.

Declining Ozone Shield



The graph shows ozone levels in the stratosphere from the 1960s to the late 1990s. Use the graph to answer the following questions.

1. **Using Tables and Graphs** Describe the general trend shown by the graph.
2. **Using Tables and Graphs** In what year did ozone drop to its lowest level?
3. **Applying Concepts** What happened between 1995 and 1999? Relate this to international actions regarding CFCs.

Global Climate Change

All life on Earth depends on climate conditions such as temperature and rainfall. That's why many ecologists are concerned about strong evidence that climate is changing. Since the late nineteenth century, average atmospheric temperatures on Earth's surface have risen about 0.6 Celsius degrees. Data from sources such as the National Oceanic and Atmospheric Administration indicate that since about 1980, average temperatures have risen between 0.2 and 0.3 Celsius degrees. The 1990s were the warmest decade ever recorded, and 1998 was the warmest year since record-keeping began. The term used to describe this increase in the average temperature of the biosphere is **global warming.** One sign of global warming is melting polar ice, as shown in **Figure 6–21.**

Evidence of Global Warming The geological record shows that Earth's climate has changed repeatedly during its history. Therefore, researchers must determine whether the current warming trend is part of a larger, natural cycle of climate change, or whether it is caused by human activity. Research focuses on describing the warming trend, determining its cause, and predicting its effects on the biosphere.

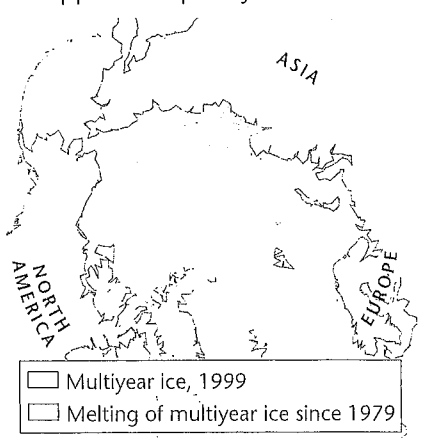
The most widely accepted hypothesis is that current warming is related, at least in part, to human activities that are adding carbon dioxide and other greenhouse gases to the atmosphere. According to this hypothesis, the burning of fossil fuels, combined with the cutting and burning of forests worldwide, is adding carbon dioxide to the atmosphere faster than the carbon cycle removes it. Data show that concentrations of carbon dioxide in the atmosphere have been rising for 200 years. As a result, the atmosphere's natural greenhouse effect is intensified, causing the atmosphere to retain more heat.

Possible Effects of Global Warming How far might this warming go and what might its effects be? Researchers attempt to answer these questions with computer models based on data. Because these models are complex and involve assumptions, their predictions are open to debate. Nevertheless, most recent models suggest that average global surface temperatures will increase by 1 to 2 Celsius degrees by the year 2050.

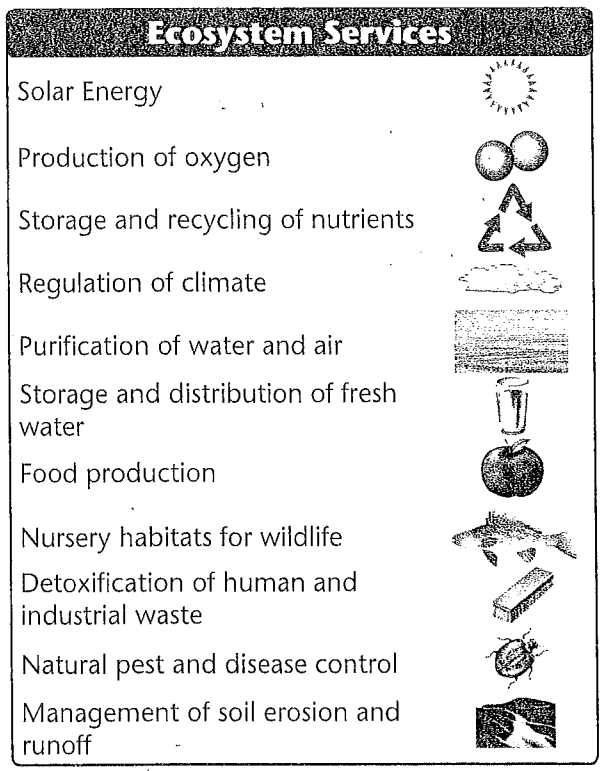
What might this change mean? Sea levels may rise enough to flood some coastal areas. Flooding would affect coastal ecosystems as well as human communities. Some models suggest that parts of North America may experience more droughts during the summer growing season. Any long-term change in climate will affect ecosystems. New organisms may be able to live in places where they once could not. Other organisms may become threatened or extinct in areas where they once thrived.

Researchers are continuing to gather data and will use the data to refine current models. The new information should help provide society with ways of dealing with climate change.

▼ Figure 6–21 Biologists are concerned about global warming. This map of the Arctic is based on images taken by satellites in 1979 and 1999. Sea ice in the Arctic Ocean has receded so quickly that some scientists suggest that, within the next 50 years, the ice could disappear completely.



Ecosystem Services



▲ **Figure 6–22** Human society depends on healthy, diverse, and productive ecosystems because of the environmental and economic benefits they provide. **Classifying** *Should the ecosystem services in the chart be considered renewable or nonrenewable resources? Explain.*

The Value of a Healthy Biosphere

You might wonder why ecologists work so hard to study what seem to be small environmental changes. To understand, remember the concept of ecosystem goods and services. As shown in **Figure 6–22,** these range from water purification to waste recycling. Ecosystems provide many services besides these, however, such as the pollination of many crop plants by insects. Ecosystems are also a reservoir of organisms that might one day provide humans with new medicines and new varieties of crops. There is much that we don't understand about the systems that provide these services. Biologists are therefore concerned that human activities might affect them in unexpected ways.

Is there any way that people can help maintain the health of the biosphere without drastically changing their lifestyles? The answer is yes. People can make wise choices in the use and conservation of resources. For example, when people water gardens or take showers, they can avoid using more water than necessary. Like the Polynesians who settled Hawaii, people can plant trees to replace the ones they have cut down. Trash and other wastes can often be reused or recycled, and dangerous chemical wastes can be disposed in a way that does not harm ecosystems. Many communities now have facilities for recycling trash and methods of safely removing hazardous materials.

Studies of human impact on the environment are not about predicting disaster. You have seen how research led to actions that are replenishing fisheries in the North Atlantic and preserving the ozone layer. The biosphere is strong. Humans are very clever. Both humans and natural ecosystems can adapt to change of different kinds.

6–4 Section Assessment

1. **Key Concept** What are two major global changes affecting the biosphere today?
2. Why is the ozone layer important to living things?
3. How could a worldwide increase in temperature affect organisms?
4. What actions can people take in their daily lives to make wise choices in the use and conservation of resources?
5. **Thinking Critically Evaluating** Evaluate the impact of environmental research on the problem of ozone depletion. How did research identify the cause of the problem? To what action did this research lead?

You & Your Community

Comparing Media

Locate five print, radio, television, or Internet sources about global warming or the ozone hole. What attitudes and opinions are expressed in these sources? Compare them with the information in this section.