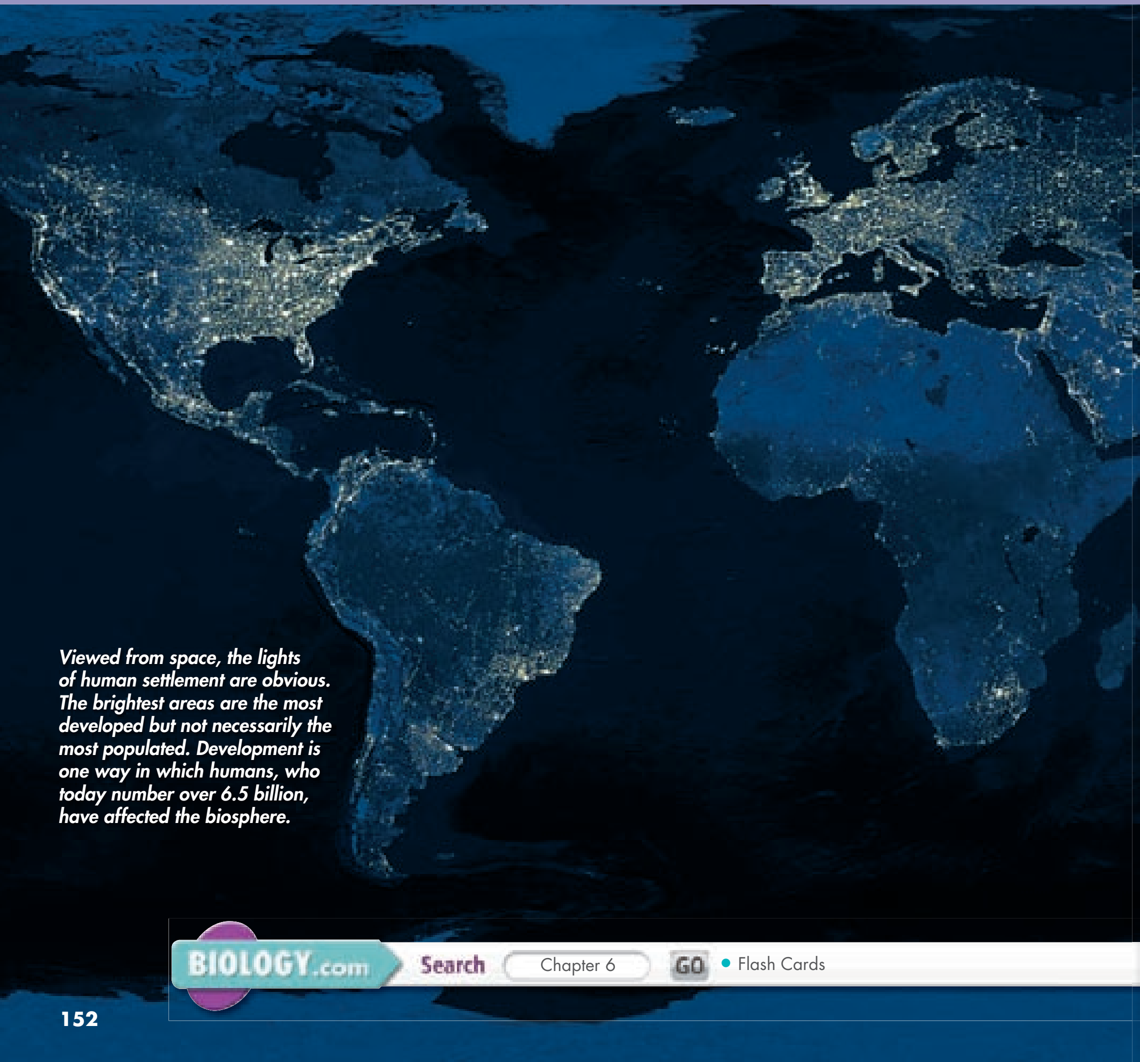
6 Humans in the Biosphere

Big idea: Interdependence in Nature

Q: How have human activities shaped local and global ecology?



Viewed from space, the lights of human settlement are obvious. The brightest areas are the most developed but not necessarily the most populated. Development is one way in which humans, who today number over 6.5 billion, have affected the biosphere.

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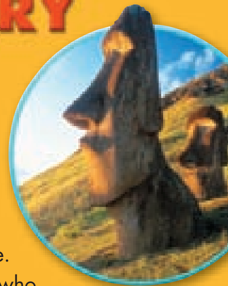
INSIDE:

- Untamed Science Video
- Chapter Mystery

CHAPTER **MYSTERY**



MOVING THE *MOAI*

Easter Island is a tiny speck of land in the vast Pacific Ocean off the coast of Chile with a harsh tropical climate. The original islanders, who called themselves Rapa Nui, came from Polynesia. They carved hundreds of huge stone statues called *moai* (moh eye). Starting around 1200 A.D., the Rapa Nui somehow moved these mysterious statues, each of which weighed between 10 and 14 tons, from quarries to locations around the island. Nearly all theories about this process suggest that strong, large logs were necessary to move the *moai*. Yet by the time Europeans landed on the island in 1722, there was no sign of any trees large enough to provide such logs. What had happened? As you read this chapter, look for clues about the interactions of the Rapa Nui with their island environment. Then, solve the mystery.

Never Stop Exploring Your World. The mystery of the moving *Moais* is just the beginning. Take a video field trip with the ecogeeks of Untamed Science to see where this mystery leads.

UntamedScience

6.1 A Changing Landscape

Key Questions

How do our daily activities affect the environment?

What is the relationship between resource use and sustainable development?

Vocabulary

monoculture
renewable resource
nonrenewable resource
sustainable development

Taking Notes

Outline As you read, create an outline using the green and blue heads in this lesson. As you read, fill in key words, phrases, and ideas about each heading.

MYSTERY CLUE

Easter Island's first colonists brought with them banana trees, taro root, and chickens—and possibly some small mammalian "stowaways." What impact might these new organisms have had on the island's ecosystems?

THINK ABOUT IT The first humans to settle Hawaii came from Polynesia about 1600 years ago. These island people had customs that protected the natural resources of their new home. For example, they were prohibited from catching certain fish during spawning season and, for every coconut palm tree cut down, they had to plant two palms in its place. But Hawaiians did not treat their islands entirely like nature reserves. They cut trees to plant farms, and they introduced nonnative plants, pigs, chickens, dogs, and rats. This combination drove many native plant and animal species to extinction. Yet for centuries Hawaii's ecosystems provided enough fresh water, fertile soil, fish, and other resources to keep the society self-sufficient. What happened next is a lesson on managing limited resources—a lesson that is as important today as it was over 1000 years ago.

The Effect of Human Activity

How do our daily activities affect the environment?

Beginning in the late 1700s, new waves of settlers arrived in Hawaii. These people did not seem to understand the limits of island ecosystems. They imported dozens more plants and animals that became invasive pests. They cleared vast tracts of forest to grow sugar cane, pineapples, and other crops that required lots of water. And as the island's human population grew, they converted untouched land for other uses, including housing and tourism, as shown in **Figure 6–1.** The effect of these activities on Hawaii's ecosystems and its human inhabitants offers a window onto a globally important question: What happens when a growing human population does not adequately manage natural resources that are both vital and limited?

FIGURE 6–1 The Lesson of Hawaii Kalalau Valley along the Na Pali coast of Kauai looks almost untouched by humans. In contrast, Waikiki Beach on the island of Oahu is surrounded by built-up areas that support tourism.

Living on Island Earth Humans, like all forms of life, rely on Earth's life-support systems. And like all other organisms, we affect our environment when we obtain food, eliminate waste products, and build places to live. The effects of these activities can be most obvious on islands such as Hawaii because of their small size. Living on an island also can make people aware of limited resources and of an area's carrying capacity for humans because anything not available locally must be brought in from far away.

Most of us who live on large continents, however, probably don't think of land, food, and water as limited resources. In the past, environmental problems were local. There was always new land to settle and new sources of food and water. But today human activity has used or altered roughly half of all the land that's not covered with ice and snow. Some people suggest that as the global population reaches 7 billion people, we may be approaching the carrying capacity of the biosphere for humans. **Humans affect regional and global environments through agriculture, development, and industry in ways that have an impact on the quality of Earth's natural resources, including soil, water, and the atmosphere.**

In Your Notebook *Explain how Earth is like an island.*

Agriculture Agriculture is one of the most important inventions in human history. A dependable supply of food that can be stored for later use enabled humans to gather in settlements that grew into towns and cities. Settlements, in turn, encouraged the growth of modern civilization—government, laws, writing, and science. Modern agricultural practices have enabled farmers to double world food production over the last 50 years. **Monoculture,** for example, is the practice of clearing large areas of land to plant a single highly productive crop year after year, like the soybeans in **Figure 6–2.** Monoculture enables efficient sowing, tending, and harvesting of crops using machines. However, providing food for nearly 7 billion people impacts natural resources, including fresh water and fertile soil. Fertilizer production and farm machinery also consume large amounts of fossil fuels.

Quick Lab
GUIDED INQUIRY

Reduce, Reuse, Recycle

1. Collect one day's worth of dry trash.
2. Sort the trash into items that can be reused, recycled, or discarded because they can't be reused or recycled.

Analyze and Conclude

1. **Analyze Data** Look at the trash you've sorted. Roughly what percentage of the total does each type represent?
2. **Predict** What do you think happens to the trash you produce? Think of at least three ways trash can impact living things.
3. **Evaluate** List three ways you can reduce the amount of trash you produce.

BUILD Vocabulary

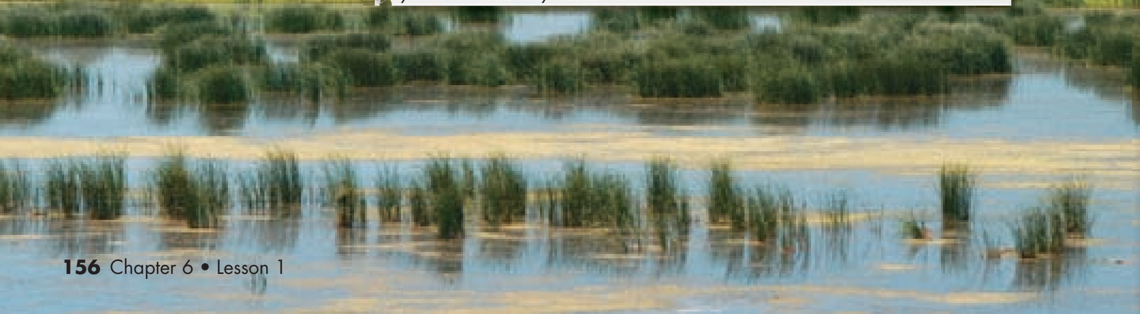
PREFIXES The prefix *mono-* in **monoculture** means "one, alone, single." Monoculture is the practice of planting a single productive crop, year after year.

FIGURE 6–2 Monoculture This farmer is using a tractor to plow a large field of soybeans.
Apply Concepts *How has agriculture helped shape civilization?*

Development As modern society developed, many people chose to live in cities. In the United States, as urban centers became crowded, people moved to, and built up, suburbs. The growth of cities and suburbs is tied to the high standard of living that Americans enjoy. Yet this development has environmental effects. Dense human communities produce lots of wastes. If these wastes are not disposed of properly, they affect air, water, and soil resources. In addition, development consumes farmland and divides natural habitats into fragments.

Industrial Growth Human society was transformed by the Industrial Revolution of the 1800s. Today, industry and scientific know-how provide us with the conveniences of modern life—from comfortable homes and clothes to electronic devices for work and play. Of course these conveniences require a lot of energy to produce and power. We obtain most of this energy by burning fossil fuels—coal, oil, and natural gas—and that affects the environment. In addition, industries have traditionally discarded wastes from manufacturing and energy production directly into the air, water, and soil.

FIGURE 6–3 Ecosystem Services Hopper Marsh is one of the wetlands controlled by The Wetlands Initiative—an organization dedicated to protecting and restoring Illinois's wetlands. The area, originally drained for farming in 1900, is shown in the inset before its 2003 restoration. **Apply Concepts** *What ecological services do wetlands provide?*



Sustainable Development

What is the relationship between resource use and sustainable development?

In the language of economics, *goods* are things that can be bought and sold, that have value in terms of dollars and cents. *Services* are processes or actions that produce goods. Ecosystem goods and services are the goods and services produced by ecosystems that benefit the human economy.

Ecosystem Goods and Services Some ecosystem goods and services—like breathable air and drinkable water—are so basic that we often take them for granted. Healthy ecosystems provide many goods and services naturally and largely free of charge. But, if the environment can't provide these goods and services, society must spend money to produce them. In many places, for example, drinkable water is provided naturally by streams, rivers, and lakes, and filtered by wetlands like the one in **Figure 6–3.** But if water sources or wetlands are polluted or damaged, water quality may fall. In such cases, cities and towns must pay for mechanical or chemical treatment to provide safe drinking water.

In Your Notebook *Describe three ecosystem goods and services you've used today.*

Renewable and Nonrenewable Resources Ecosystem goods and services are classified as either renewable or nonrenewable, as shown in **Figure 6–4.** A **renewable resource** can be produced or replaced by a healthy ecosystem. A single southern white pine 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. But some resources are **nonrenewable resources** because natural processes cannot replenish them within a reasonable amount of time. Fossil fuels like coal, oil, and natural gas are nonrenewable resources formed from buried organic materials over millions of years. When existing deposits are depleted, they are essentially gone forever.

Sustainable Resource Use Ecological science can teach us how to use natural resources to meet our needs without causing long-term environmental harm. Using resources in such an environmentally conscious way is called **sustainable development.** **Sustainable development provides for human needs while preserving the ecosystems that produce natural resources.**

What should sustainable development look like? It should cause no long-term harm to the soil, water, and climate on which it depends. It should consume as little energy and material as possible. Sustainable development must be flexible enough to survive environmental stresses like droughts, floods, and heat waves or cold snaps. Finally, sustainable development must take into account human economic systems as well as ecosystem goods and services. It must do more than just enable people to survive. It must help them improve their situation.

FIGURE 6–4 Natural Resources Natural resources are classified as renewable or nonrenewable. Wind and coal are both natural resources that can provide energy. But wind is renewable, while coal—like other fossil fuels—is not.

6.1 Assessment

Review Key Concepts

1. a. **Review** List the three primary types of human activities that have affected regional and global environments. For each, give one benefit and one environmental cost.
   b. **Relate Cause and Effect** How might more productive agricultural practices affect a developing nation's population? Its environmental health?
   c. **Apply Concepts** In addition to filtering water, wetlands provide flood control by absorbing excess water. Explain how society would provide these services (for a cost) if the ecosystem could not.

2. a. **Review** What is sustainable development? How can it help minimize the negative impacts of human activities?
   b. **Explain** Explain why energy from the sun is a renewable resource but energy from oil is a nonrenewable resource.

WRITE ABOUT SCIENCE

Description

3. What signs of growth do you see in your community? Write a paragraph telling how this growth might affect local ecosystems.

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6.2 Using Resources Wisely

Key Questions

Why is soil important, and how do we protect it?

What are the primary sources of water pollution?

What are the major forms of air pollution?

Vocabulary

desertification
deforestation
pollutant
biological magnification
smog
acid rain

Taking Notes

Concept Map As you read, create a concept map to organize the information in this lesson.

THINK ABOUT IT Our economy is built on the use of natural resources, so leaving those resources untouched is not an option. Humans need to eat, for example, so we can't just stop cultivating land for farming. But the goods and services provided by healthy ecosystems are essential to life. We can't grow anything in soil that has lost its nutrients due to overfarming. If we don't properly manage agriculture, then, we may one day lose the natural resource on which it depends. So how do we find a balance? How do we obtain what we need from local and global environments without destroying those environments?

Soil Resources

Why is soil important, and how do we protect it?

When you think of natural resources, soil may not be something that comes to mind. But many objects you come into contact with daily rely on soil—from the grain in your breakfast cereal, to the wood in your home, to the pages of this textbook. **Healthy soil supports both agriculture and forestry.** The mineral- and nutrient-rich portion of soil is called topsoil. Good topsoil absorbs and retains moisture yet allows water to drain. It is rich in organic matter and nutrients, but low in salts. Good topsoil is produced by long-term interactions between soil and the plants growing in it.

Topsoil can be a renewable resource if it is managed properly, but it can be damaged or lost if it is mismanaged. Healthy soil can take centuries to form but can be lost very quickly. And the loss of fertile soil can have dire consequences. Years of poorly managed farming in addition to severe drought in the 1930s badly eroded the once-fertile soil of the Great Plains. Thousands upon thousands of people lost their jobs and homes. The area essentially turned to desert, or, as it came to be known, a "dust bowl," as seen in **Figure 6–5.** What causes soil erosion, and how can we prevent it?

FIGURE 6–5 The Dust Bowl A ranch in Boise City, Idaho, is about to be hit by a cloud of dry soil on April 15, 1935.

Soil Erosion The dust bowl of the 1930s was caused, in part, by conversion of prairie land to cropland in ways that left soil vulnerable to erosion. Soil erosion is the removal of soil by water or wind. Soil erosion is often worse when land is plowed and left barren between plantings. When no roots are left to hold soil in place, it is easily washed away. And when soil is badly eroded, organic matter and minerals that make it fertile are often carried away with the soil. In parts of the world with dry climates, a combination of farming, overgrazing, seasonal drought, and climate change can turn farmland into desert. This process is called **desertification,** and it is what happened to the Great Plains in the 1930s. Roughly 40 percent of Earth's land is considered at risk for desertification. **Figure 6–6** shows vulnerable areas in North and South America.

Deforestation, or loss of forests, can also have a negative effect on soil quality. Healthy forests not only provide wood, but also hold soil in place, protect the quality of fresh water supplies, absorb carbon dioxide, and help moderate local climate. Unfortunately, more than half of the world's old-growth forests (forests that had never been cut) have already been lost to deforestation. In some temperate areas, such as the Eastern United States, forests can regrow after cutting. But it takes centuries for succession to produce mature, old-growth forests. In some places, such as in parts of the tropics, forests don't grow back at all after logging. This is why old-growth forests are usually considered nonrenewable resources.

Deforestation can lead to severe erosion, especially on mountainsides. Grazing or plowing after deforestation can permanently change local soils and microclimates in ways that prevent the regrowth of trees. Tropical rain forests, for example, look lush and rich, so you might assume they would grow back after logging. Unfortunately, topsoil in these forests is generally thin, and organic matter decomposes rapidly under high heat and humidity. When tropical rain forests are cleared for timber or for agriculture, their soil is typically useful for just a few years. After that the areas become wastelands, the harsh conditions there preventing regrowth.

In Your Notebook *Describe the relationship between agriculture and soil quality.*

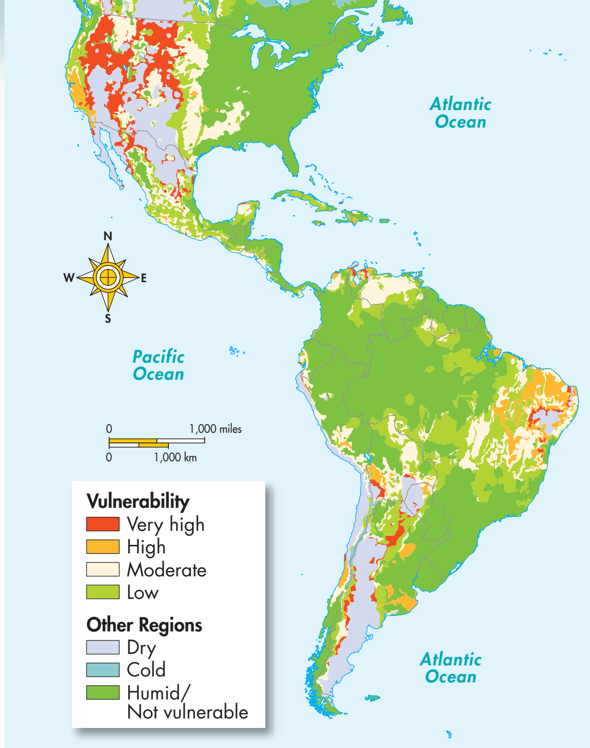


FIGURE 6–6 Desertification Risk The U.S. Department of Agriculture assigns desertification risk categories based on soil type and climate. **Interpret Visuals** *Find your approximate location on the map. What category of desertification risk is your area in?*

MYSTERY CLUE

Forests of palm trees with strong, tall trunks and edible seeds once covered most of Easter Island. Why would the islanders have cut down these forests? What effect would deforestation have had?

FIGURE 6–7 Contour Plowing Planting crops parallel to the land's natural contours can help reduce soil erosion.

Soil Use and Sustainability **It is possible to minimize soil erosion through careful management of both agriculture and forestry.** Soil is most vulnerable to erosion when it is completely bare. Leaving stems and roots of the previous year's crop in the soil can help hold soil in place between plantings. And because different plants take different nutrients from the soil, crop rotation—planting different crops at different seasons or in different years—can help prevent both erosion and nutrient loss.

Altering the shape of the land is another way to limit erosion. The practice of contour plowing, shown in **Figure 6–7,** involves planting fields of crops across, instead of down, the slope of the land. This can reduce water runoff and therefore erosion. Similarly, terracing—shaping the land to create level "steps"—helps hold water and soil.

What are options for sustainable forestry? Selectively harvesting mature trees can promote the growth of younger trees and preserve the forest ecosystem, including its soil. In the southeastern United States, conditions enable foresters to plant, harvest, and replant tree farms. A well-managed tree farm both protects the soil and makes the trees themselves a renewable resource.

Freshwater Resources

What are the primary sources of water pollution?

Humans depend on fresh water and freshwater ecosystems for goods and services, including drinking water, industry, transportation, energy, and waste disposal. Some of the most productive American farmland relies heavily on irrigation, in which fresh water is brought in from other sources.

While fresh water is usually considered a renewable resource, some sources of fresh water are not renewable. The Ogallala aquifer, for example, spans eight states from South Dakota to Texas. The aquifer took more than a million years to collect and is not replenished by rainfall today. So much water is being pumped out of the Ogallala that it is expected to run dry in 20 to 40 years. In many places, freshwater supplies are limited. Only 3 percent of Earth's water is fresh water—and most of that is locked in ice at the poles. Since we can't infinitely expand our use of a finite resource, we must protect the ecosystems that collect and purify fresh water.

Water Pollution Freshwater sources can be affected by different kinds of pollution. A **pollutant** is a harmful material that can enter the biosphere. Sometimes pollutants enter water supplies from a single source—a factory or an oil spill, for example. This is called point source pollution. Often, however, pollutants enter water supplies from many smaller sources—the grease and oil washed off streets by rain or the chemicals released into the air by factories and automobiles. These pollutants are called nonpoint sources.

Pollutants may enter both surface water and underground water supplies that we access with wells. Once contaminants are present, they can be extremely difficult to get rid of. **The primary sources of water pollution are industrial and agricultural chemicals, residential sewage, and nonpoint sources.**

▶ ***Industrial and Agricultural Chemicals*** One industrial pollutant is a class of organic chemicals called PCBs that were widely used in industry until the 1970s. After several large-scale contamination events, PCBs were banned. However, because PCBs often enter mud and sand beneath bodies of water, they can be difficult, if not impossible, to eliminate. Parts of the Great Lakes and some coastal areas, for example, are still polluted with PCBs. Other harmful industrial pollutants are heavy metals like cadmium, lead, mercury, and zinc.

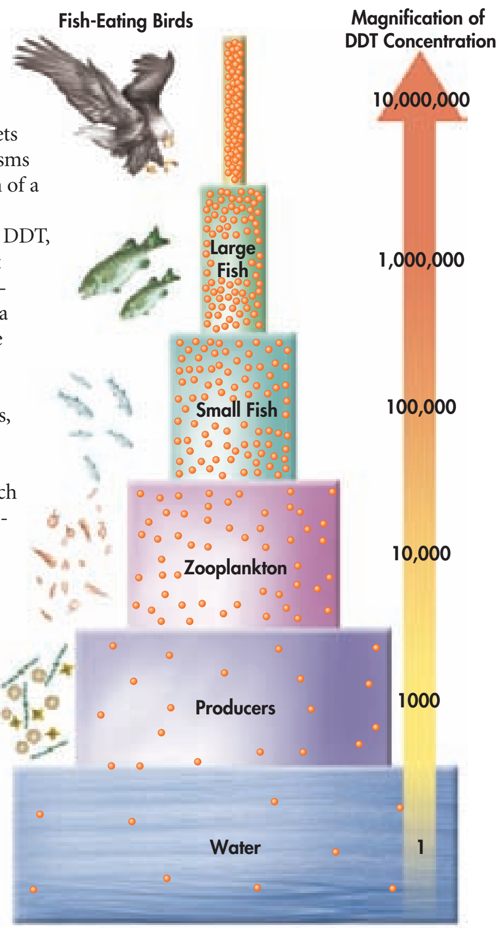
Large-scale monoculture has increased the use of pesticides and insecticides. These chemicals can enter the water supply in the form of runoff after heavy rains, or they can seep directly into groundwater. Pesticides can be very dangerous pollutants. DDT, which is both cheap and long lasting, effectively controls agricultural pests and disease-carrying mosquitoes. But when DDT gets into a water supply, it has disastrous effects on the organisms that directly and indirectly rely on that water—a function of a phenomenon called biological magnification.

Biological magnification occurs if a pollutant, such as DDT, mercury, or a PCB, is picked up by an organism and is not broken down or eliminated from its body. Instead, the pollutant collects in body tissues. Primary producers pick up a pollutant from the environment. Herbivores that eat those producers concentrate and store the compound. Pollutant concentrations in herbivores may be more than ten times the levels in producers. When carnivores eat the herbivores, the compound is still further concentrated. Thus, pollutant concentration increases at higher trophic levels. In the highest trophic levels, pollutant concentrations may reach 10 million times their original concentration in the environment, as shown in **Figure 6–8.**

These high concentrations can cause serious problems for wildlife and humans. Widespread DDT use in the 1950s threatened fish-eating birds like pelicans, osprey, falcons, and bald eagles. It caused females to lay eggs with thin, fragile shells, reducing hatching rates and causing a drop in bird populations. Since DDT was banned in the 1970s, bird populations have recovered. Still a concern is mercury, which accumulates in the bodies of certain marine fish such as tuna and swordfish.

In Your Notebook *In your own words, explain the process of biological magnification.*

FIGURE 6–8 Biological Magnification In the process of biological magnification, the concentration of a pollutant like DDT—represented by the orange dots—is multiplied as it passes up the food chain from producers to consumers. **Calculate** ***By what number is the concentration of DDT multiplied at each successive trophic level?*** MATH



▶ ***Residential Sewage*** Have you ever stopped to think what happens after you flush your toilet? Those wastes don't disappear! They become residential sewage. Sewage isn't poisonous, but it does contain lots of nitrogen and phosphorus. Reasonable amounts of these nutrients can be processed by and absorbed into healthy ecosystems. But large amounts of sewage can stimulate blooms of bacteria and algae that rob water of oxygen. Oxygen-poor areas called "dead zones" can appear in both fresh and salt water. Raw sewage also contains microorganisms that can spread disease.

Water Quality and Sustainability One key to sustainable water use is to protect the natural systems involved in the water cycle. For example, as water flows slowly through a wetland, densely growing plants absorb some excess nutrients and filter out certain pollutants. Similarly, forests and other vegetation help purify water that seeps into the ground or runs off into rivers and lakes. Protecting these ecosystems is a critical part of watershed conservation. A watershed includes all the land whose groundwater, streams, and rivers drain into the same place—such as a large lake or river. The idea behind watershed conservation is simple: Cleaning up the pollution in a local area can't do much good if the water running into it is polluted. You must consider the entire watershed to achieve long-lasting results.

Pollution control can have direct and positive effects on the water quality in a watershed. Sewage treatment can lower levels of sewage-associated bacteria and help prevent dead zones in bodies of water receiving the runoff. In some situations, agriculture can use integrated pest management (IPM) instead of pesticides. IPM techniques include biological control—using predators and parasites to regulate for pest insects—the use of less-poisonous sprays, and crop rotation.

Conserving water is, of course, also important. One example of water conservation in agriculture is drip irrigation, shown in **Figure 6–9,** which delivers water drop by drop directly to the roots of plants that need it.

BUILD Vocabulary

RELATED WORD FORMS The verb *purify* is related to the noun *pure*. *To purify* means "to make pure or clean." Wetlands purify water by removing pollutants.

FIGURE 6–9 Drip Irrigation These cabbages are supplied water directly to their roots through drip irrigation. Tiny holes in water hoses (inset) allow farmers to deliver water only where it's needed.

Atmospheric Resources

What are the major forms of air pollution?

The atmosphere is a common resource whose quality has direct effects on health. After all, the atmosphere provides the oxygen we breathe! In addition, ozone, a form of oxygen that is found naturally in the upper atmosphere, absorbs harmful ultraviolet radiation from sunlight before it reaches Earth's surface. It is the ozone layer that protects our skin from damage that can cause cancer.

The atmosphere provides many other services. For example, the atmosphere's greenhouse gases, including carbon dioxide, methane, and water vapor, regulate global temperature. As you've learned, without the greenhouse effect, Earth's average temperature would be about 30° Celsius cooler than it is today.

The atmosphere is never "used up." So, classifying it as a renewable or nonrenewable resource is not as important as understanding how human activities affect the quality of the atmosphere. For most of Earth's history, the quality of the atmosphere has been naturally maintained by biogeochemical cycles. However, if we disrupt those cycles, or if we overload the atmosphere with pollutants, the effects on its quality can last a very long time.

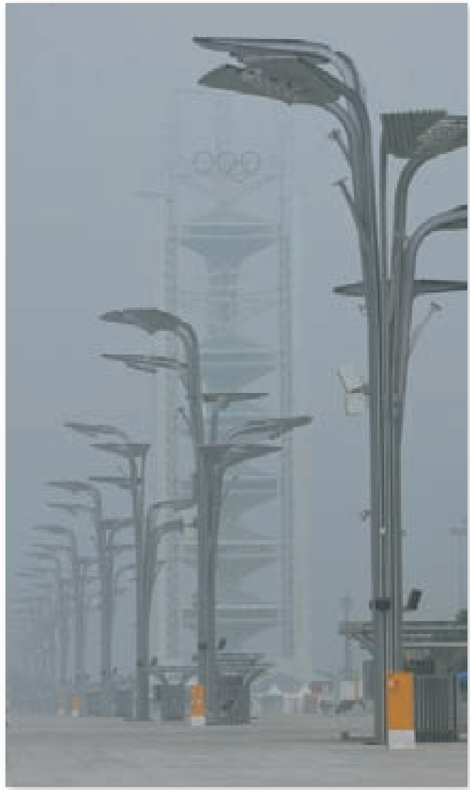


FIGURE 6–10 Smog Despite closing factories and restricting vehicle access to the city, Beijing remained under a blanket of dense smog just days before the 2008 Summer Olympics. **Apply Concepts** *What component of smog is beneficial when part of the atmosphere, but harmful when at ground level?*

Air Pollution What happens when the quality of Earth's atmosphere is reduced? For one thing, respiratory illnesses such as asthma are made worse and skin diseases tend to increase. Globally, climate patterns may be affected. What causes poor air quality? Industrial processes and the burning of fossil fuels can release pollutants of several kinds. **Common forms of air pollution include smog, acid rain, greenhouse gases, and particulates.**

▶ ***Smog*** If you live in a large city, you've probably seen **smog,** a gray-brown haze formed by chemical reactions among pollutants released into the air by industrial processes and automobile exhaust. Ozone is one product of these reactions. While ozone high up in the atmosphere helps protect life on Earth from ultraviolet radiation, at ground level, ozone and other pollutants threaten the health of people, especially those with respiratory conditions. Many athletes participating in the 2008 Summer Olympics in Beijing, China, expressed concern over how the intense smog, seen in **Figure 6–10,** would affect their performance and health.

In Your Notebook *Compare and contrast the atmosphere as a resource with fresh water as a resource.*

Analyzing Data

American Air Pollution Trends

Each year, the U.S. Environmental Protection Agency (EPA) estimates emissions from a variety of sources. Look at the graph in **Figure 6–12.** The combined emissions of six common pollutants are plotted along with trends in energy consumption and automobile travel between 1980 and 2007. The values shown are the total percentage change. For example, in 1995, aggregate emissions had dropped about 30 percent from their level in 1980.

1. **Interpret Data** Describe the overall trend in emissions since 1980. Is this what you would expect given the trends in energy consumption and automobile travel? Explain your answer.
2. **Interpret Data** How does this graph differ from one that shows *absolute* values for emissions? Would that graph start at zero as this one does?
3. **Infer** What do you think has contributed to the trends you see in this graph? Why would the EPA be particularly interested in these data?

FIGURE 6–11 Acid Rain Acid rain results from the chemical transformation of nitrogen and sulfur products that come from human activities. These reactions can cause damage to stone statues and plant life.

▶ ***Acid Rain*** When we burn fossil fuels in our factories and homes, we release nitrogen and sulfur compounds. When those compounds combine with water vapor in the air, they form nitric and sulfuric acids. These airborne acids can drift for many kilometers before they fall as **acid rain.** Acidic water vapor can also affect ecosystems as fog or snow. In some areas, acid rain kills plants by damaging their leaves and changing the chemistry of soils and surface water. Examples of its effects are shown in **Figure 6–11.** Acid precipitation also can dissolve and release mercury and other toxic elements from soil, freeing those elements to enter other parts of the biosphere.

In Your Notebook *Create a flowchart that shows the steps in acid rain formation.*

▶ ***Greenhouse Gases*** Burning fossil fuels and forests releases stored carbon into the atmosphere as carbon dioxide, a greenhouse gas. Agricultural practices from raising cattle to farming rice release methane, another greenhouse gas. Although some greenhouse gases are necessary, when excess greenhouse gases accumulate in the atmosphere, they contribute to global warming and climate change.

▶ ***Particulates*** Particulates are microscopic particles of ash and dust released by certain industrial processes and certain kinds of diesel engines. Very small particulates can pass through the nose and mouth and enter the lungs, where they can cause serious health problems.

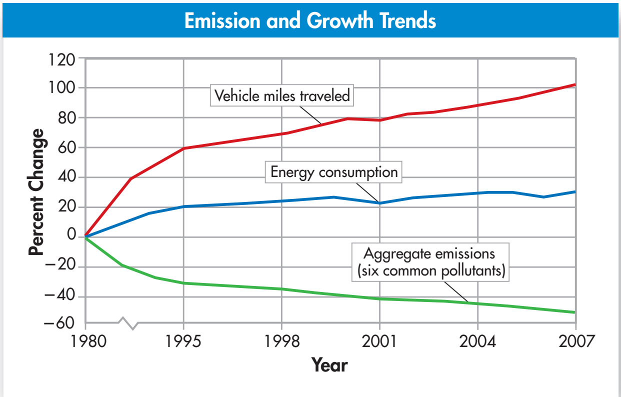


FIGURE 6–12 Air Pollution Trends This graph summarizes EPA findings of the total percentage change from 1980 to 2007 in vehicle miles traveled, energy consumption, and the combined emissions of six common pollutants—carbon monoxide, lead, nitrogen oxides, organic compounds, particulates, and sulfur dioxide. **Calculate** ***In 1980, motorists in the Puget Sound region of Washington State traveled 36.4 million miles. Assuming that these motorists increased their miles traveled at the national rate, approximately how many miles did they travel in 2007?*** MATH

Air Quality and Sustainability Improving air quality is difficult. Air doesn't stay in one place and doesn't "belong" to anyone. Automobile emission standards and clean-air regulations have improved air quality in some regions, however, and seem to be having a net positive effect, as shown in **Figure 6–12.** Efforts like these also have improved the atmosphere globally. At one time, for example, all gasoline was enriched with lead. But as leaded gasoline burned, lead was released in exhaust fumes and ultimately washed onto land and into rivers and streams. U.S. efforts to phase out leaded gasoline started in 1973 and were completed in 1996 when the sale of leaded gasoline was banned. Now that unleaded gasoline is used widely across the United States, lead levels in soils, rivers, and streams around the country have dropped significantly from earlier, higher levels.

6.2 Assessment

Review Key Concepts

1. a. Review What causes soil erosion? Why is soil erosion a problem?

b. Apply Concepts What are three ways in which the agriculture and forestry industries can improve the sustainability of soil?

2. a. Review How is fresh water both a renewable and a limited resource?

b. Explain Why are some pollutants more harmful to organisms at higher trophic levels?

c. Propose a Solution Pick one source of water pollution and describe a way in which we can reduce its effect.

3. a. Review What ecological goods and services does the atmosphere provide?

b. Relate Cause and Effect How does the use of fossil fuels negatively impact Earth's atmosphere?

ANALYZING DATA

4. Look at **Figure 6–8.** If the concentration of DDT in zooplankton measures 0.04 parts per million, what is the approximate concentration of DDT at each other trophic level shown? MATH

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6.3 Biodiversity

Key Questions

Why is biodiversity important?

What are the most significant threats to biodiversity?

How do we preserve biodiversity?

Vocabulary

biodiversity
ecosystem diversity
species diversity
genetic diversity
habitat fragmentation
ecological hot spot

Taking Notes

Preview Visuals Before you read, look at **Figure 6–20.** Record three questions you have about the map. When you've finished reading, answer the questions.

THINK ABOUT IT Those of us who love nature are awed by the incredible variety of living things that share our planet. From multicolored coral reefs to moss-draped forests, *variety*, is "the spice of life." But variety in the biosphere gives us more than interesting things to look at. Our well-being is closely tied to the well-being of a great number of other organisms, including many that are neither majestic nor beautiful to our eyes.

The Value of Biodiversity

Why is biodiversity important?

Biological diversity, or **biodiversity,** is the total of all the genetically based variation in all organisms in the biosphere. To biologists, biodiversity is precious, worth preserving for its own sake. But what kinds of biodiversity exist, and what value do they offer society?

Types of Biodiversity Biodiversity exists on three levels: ecosystem diversity, species diversity, and genetic diversity. **Ecosystem diversity** refers to the variety of habitats, communities, and ecological processes in the biosphere. The number of different species in the biosphere, or in a particular area, is called **species diversity.** To date, biologists have identified and named more than 1.8 million species, and they estimate that at least 30 million more are yet be discovered. Much of this diversity exists among single-celled organisms. But new species of vertebrates, like the snake in **Figure 6–13,** are still being found.

Genetic diversity can refer to the sum total of all different forms of genetic information carried by a particular species, or by all organisms on Earth. Within each species, genetic diversity refers to the total of all different forms of genes present in that species. In many ways, genetic diversity is the most basic kind of biodiversity. It is also the hardest kind to see and appreciate. Yet, genetic diversity is vitally important to the survival and evolution of species in a changing world.

FIGURE 6–13 A New Species This tiny snake, native to the island of Barbados, is one of many recently discovered species. Photos of the snake were released in 2008. **Infer** *Why are you more likely to discover a new vertebrate species in a tropical area than in a desert?*

Valuing Biodiversity You can't touch, smell, or eat biodiversity, so many people don't think of it as a natural resource. But biodiversity is one of Earth's greatest natural resources. **Biodiversity's benefits to society include contributions to medicine and agriculture, and the provision of ecosystem goods and services.** When biodiversity is lost, significant value to the biosphere and to humanity may be lost along with it.

▶ ***Biodiversity and Medicine*** Wild species are the original source of many medicines, including painkillers like aspirin and antibiotics like penicillin. The chemicals in wild species are used to treat diseases like depression and cancer. For example, the foxglove, shown in **Figure 6–14,** contains compounds called digitalins that are used to treat heart disease. These plant compounds are assembled according to instructions coded in genes. So the genetic information carried by diverse species is like a "natural library" from which we have a great deal to learn.

▶ ***Biodiversity and Agriculture*** Genetic diversity is also important in agriculture. Most crop plants have wild relatives, like the potatoes in **Figure 6–15.** These wild plants may carry genes we can use—through plant breeding or genetic engineering—to transfer disease or pest resistance, or other useful traits, to crop plants.

▶ ***Biodiversity and Ecosystem Services*** The number and variety of species in an ecosystem can influence that ecosystem's stability, productivity, and value to humans. Sometimes the presence or absence of a single keystone species, like the sea otter in **Figure 6–16,** can completely change the nature of life in an ecosystem. Also, healthy and diverse ecosystems play a vital role in maintaining soil, water, and air quality.

FIGURE 6–14 Medicinal Plants Digoxin, a drug derived from digitalin compounds in the foxglove plant, is used to treat heart disease.

FIGURE 6–15 Potato Diversity The genetic diversity of wild potatoes in South America can be seen in the colorful varieties shown here. The International Potato Center, based in Peru, houses a "library" of more than 4500 tuber varieties.

FIGURE 6–16 Keystone Species The sea otter is a keystone species. When the otter population falls, the population of its favorite prey, sea urchins, goes up. Population increases in sea urchins, in turn, cause a dramatic decrease in the population of sea kelp, the sea urchin's favorite food.

Threats to Biodiversity

What are the most significant threats to biodiversity?

Species have been evolving, changing, and dying out since life began. In fact scientists estimate that over 99 percent of the species that have ever lived are now extinct. So extinction is not new. But human activity today is causing the greatest wave of extinctions since dinosaurs disappeared. The current rate of species loss is approaching 1000 times the "typical" rate. And as species disappear, the potential contribution to human knowledge that is carried in their genes is lost.

Species diversity is related to genetic diversity. The more genetically diverse a species is, the greater its chances of surviving disturbances. So, as human activity reduces genetic diversity, species are put at a greater risk for extinction. Species diversity, in turn, is linked to ecosystem diversity. Therefore, as ecosystems are damaged, the organisms that inhabit them become more vulnerable to extinction.

How are humans influencing biodiversity? **Humans reduce biodiversity by altering habitats, hunting, introducing invasive species, releasing pollution into food webs, and contributing to climate change.** Biologists compare loss of biodiversity to destroying a library before its books are ever read.

Altered Habitats When natural habitats are eliminated for agriculture or for urban development, the number of species in those habitats drops, and some species may become extinct. But, habitats don't need to be completely destroyed to put species at risk. Development often splits ecosystems into pieces, a process called **habitat fragmentation,** leaving habitat "islands." You probably 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, as shown in **Figure 6–17.** The smaller a habitat island, the fewer the species that can live there and the smaller their populations. Both changes make habitats and species more vulnerable to other disturbance.

MYSTERY CLUE

Easter Island probably never had the biological diversity of Hawaii and many other tropical islands. How would this affect its ability to rebound after a disturbance?

BUILD Vocabulary

ACADEMIC WORDS The adjective **vulnerable** means "open to attack or damage." Fragmented habitats are more vulnerable, or more apt to be damaged, than larger undisturbed habitats because they contain fewer species and smaller populations of organisms.

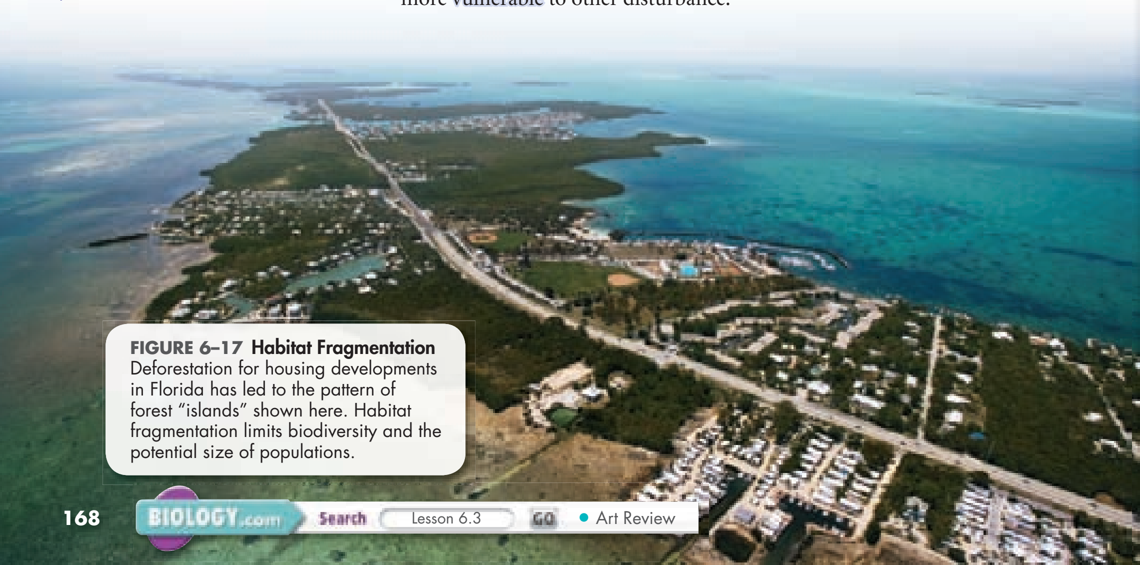


FIGURE 6–17 Habitat Fragmentation Deforestation for housing developments in Florida has led to the pattern of forest "islands" shown here. Habitat fragmentation limits biodiversity and the potential size of populations.

FIGURE 6–18 Hunted and Sold as Pets *These caged green parrots were captured in the Amazon rainforest and brought to a market in Peru.* **Infer** ***What impact do you think hunting has on the animals left behind?***

Hunting and the Demand for Wildlife Products Humans can push species to extinction by hunting. In the 1800s, hunting wiped out the Carolina parakeet and the passenger pigeon. Today endangered species in the United States are protected from hunting, but hunting still threatens rare animals in Africa, South America, and Southeast Asia. Some animals, like many birds, are hunted for meat. Others are hunted for their commercially valuable hides or skins or because people believe their body parts have medicinal properties. Still others, like the parrots in **Figure 6–18,** are hunted to be sold as pets. Hunted species are affected even more than other species by habitat fragmentation because fragmentation increases access for hunters and limits available hiding spaces for prey. The Convention on International Trade in Endangered Species (CITES) bans international trade in products from a list of endangered species. Unfortunately, it's difficult to enforce laws in remote wilderness areas.

Introduced Species Recall that organisms introduced to new habitats can become invasive and threaten biodiversity. For example, more than 130 introduced species live in the Great Lakes, where they have been changing aquatic ecosystems and driving native species close to extinction. One European weed, leafy spurge, infests millions of hectares across the Northern Great Plains. On rangelands, leafy spurge displaces grasses and other food plants, and its milky latex can sicken or kill cattle and horses. Each year, ranchers and farmers suffer losses of more than $120 million because of this single pest.

Pollution Many of the pollutants described in the last lesson also threaten biodiversity. DDT, for example, prevents birds from laying healthy eggs. In the United States, brown pelican, peregrine falcon, and other bird populations plummeted with widespread use of the chemical. Acid rain places stress on land and water organisms. Increased carbon dioxide in the atmosphere is dissolving in oceans, making them more acidic, which threatens biodiversity on coral reefs and in other marine ecosystems.

In Your Notebook *Why is acidic water harmful to coral?*

MYSTERY CLUE

Almost all the coconut shells found by researchers on Easter Island show signs of having been gnawed on by nonnative rats. Coconuts contain the seeds of the coconut palm. What effect do you think the rats had on the coconut palm population?

Climate Change Climate change (a topic in the next lesson) is a major threat to biodiversity. Remember that organisms are adapted to their environments and have specific tolerance ranges to temperature and other abiotic conditions. If conditions change beyond an organism's tolerance, the organism must move to a more suitable location or face extinction. Species in fragmented habitats are particularly vulnerable to climate change because if conditions change they may not be able to move easily to a suitable habitat. Estimates vary regarding the effects of climate change on biodiversity. If global temperatures increase 1.5°C–2.5°C over late twentieth-century temperatures, 30 percent of species studied are likely to face increased risk of extinction. If the global temperature increase goes beyond 3.5°C, it is likely that 40–70 percent of species studied will face extinction.

Conserving Biodiversity

How do we preserve biodiversity?

What can we do to protect biodiversity? Should we focus on a particular organism like the scarlet macaw? Or should we try to save an entire ecosystem like the Amazon rain forest? We must do both. At the same time, conservation efforts must take human interests into account. **To conserve biodiversity, we must protect individual species, preserve habitats and ecosystems, and make certain that human neighbors of protected areas benefit from participating in conservation efforts.**

FIGURE 6–19 Saving an Individual Species Efforts to save the giant panda include a comprehensive captive breeding and reintroduction program. Here, a researcher examines an infant panda at China's Wolong Nature Reserve. **Apply Concepts** ***How does captive breeding affect a population's genetic diversity?***

Protecting Individual Species In the past, most conservation efforts focused on individual species, and some of this work continues today. The Association of Zoos and Aquariums (AZA), for example, oversees species survival plans (SSPs) designed to protect threatened and endangered species. A key part of those plans is a captive breeding program. Members of the AZA carefully select and manage mating pairs of animals to ensure maximum genetic diversity. The ultimate goal of an SSP is to reintroduce individuals to the wild. Research, public education, and breeding programs all contribute to that goal. More than 180 species, including the giant panda shown in **Figure 6–19,** are currently covered by SSPs.

Preserving Habitats and Ecosystems The main thrust of global conservation efforts today is to protect not just individual species but entire ecosystems. The goal is to preserve the natural interactions of many species at once. To that end, governments and conservation groups work to set aside land as parks and reserves. The United States has national parks, forests, and other protected areas. Marine sanctuaries are being created to protect coral reefs and marine mammals.

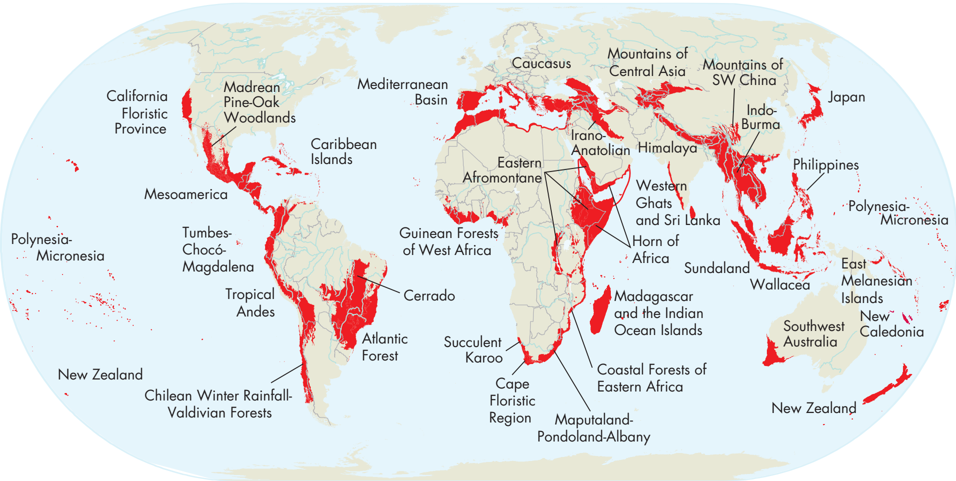


FIGURE 6–20 Ecological Hot Spots Conservation International identifies biodiversity hot spots using two criteria. The area (1) must contain at least 1500 species of native vascular plants, and (2) it must have lost at least 70 percent of its original habitat. The 34 hot spots seen here cover just 2.3 percent of Earth's land surface, but they contain over 50 percent of the world's plant species and 42 percent of its terrestrial vertebrates.

The challenge is protecting areas that are large enough and that contain the right resources to protect biodiversity. To make sure that conservation efforts are concentrated in the most important places, conservation biologists have identified ecological "hot spots," shown in red in **Figure 6–20.** An **ecological hot spot** is a place where significant numbers of species and habitats are in immediate danger of extinction. By identifying these areas, ecologists hope that scientists and governments can better target their efforts to save as many species as possible.

Considering Local Interests Protecting biodiversity often demands that individuals change their habits or the way they earn their living. In these cases it is helpful to offer some reward or incentive to the people or communities involved. The United States government, for example, has offered tax credits to people who've installed solar panels or bought hybrid cars. Similarly, many communities in Africa, Central America, and Southeast Asia have set aside land for national parks and nature reserves, like the park shown in **Figure 6–21,** to attract tourist dollars. In some Australian communities, farmers were paid to plant trees along rivers and streams as part of wildlife corridors connecting forest fragments. Not only did the trees help improve local water quality; they also improved the health of the farmers' cows, which were able to enjoy shade on hot days!

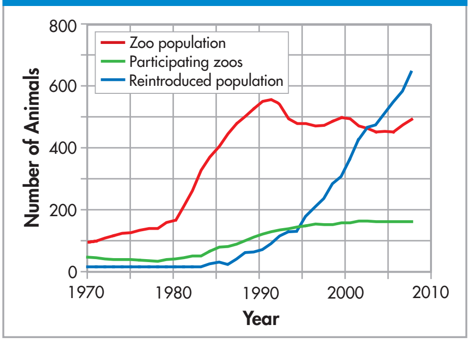
The use of carbon credits is one strategy aimed at encouraging industries to cut fossil fuels use. Companies are allowed to release a certain amount of carbon into the environment. Any unused carbon may be sold back at a set market value or traded to other companies. This strategy encourages industries to pay for lower-emission machinery and to adopt carbon-saving practices. In this way, pollution is capped or cut without adding a financial burden to the industry involved. This helps protect the economy while reducing biodiversity loss due to pollution. These examples show that conservation efforts work best when they are both informed by solid scientific information and benefit the communities affected by them.

FIGURE 6–21 Ecotourism A tourist gets an elephant-size kiss from one of the over 30 rescued elephants at Thailand's Elephant Nature Park.

Analyzing Data

Saving the Golden Lion Tamarin

Golden lion tamarins (GLTs) are primates native to the coastal regions of the Amazon rain forest. They have been threatened by habitat destruction and fragmentation. In the early 1970s, there were approximately 200 GLTs in the wild and only 91 animals in 26 zoos. As of 2007, the SSP included 496 GLTs in 145 participating zoos around the world. About 153 tamarins once part of the program have been reintroduced to the wild since 1984, resulting in a reintroduced population of more than 650.



1. Calculate By what percentage did the captive population of golden lion tamarins increase between 1970 and 2007? MATH

2. Analyze Data Reintroduction typically begins once a captive population has reached a target size—the size at which a high degree of genetic diversity can be maintained. Based on the graph, what is the approximate target captive population size for the golden lion tamarin?

3. Infer Only 153 tamarins have been reintroduced to the wild. If there are now 650 tamarins in the reintroduced population, where did the other 497 come from?

4. Form an Opinion When populations of wild animals get very small, do you think they should be removed from the wild and brought into captivity? Why or why not?

Adapted from J. D. Ballou and J. Mickelberg, *International Studbook for Golden Lion Tamarins* (Washington, D.C.: National Zoological Park, Smithsonian Institution, 2007). B. Holst et al., *Lion Tamarin Population and Habitat Viability Assessment Workshop 2005, Final Report* (Apple Valley, MN: IUCN/SSC Conservation Breeding Specialist Group, 2006.)

6.3 Assessment

Review Key Concepts

1. a. **Review** Describe the different components of global biodiversity.
   b. **Apply Concepts** What benefits does society get from biodiversity?
2. a. **Review** What are the major threats to biodiversity?
   b. **Relate Cause and Effect** Explain the relationship between habitat size and species diversity.
3. a. **Review** What is the goal of a species survival plan?
   b. **Form an Opinion** Do you think that the hot spot strategy is a good one? Explain your answer.

VISUAL THINKING

4. Look back at the biome map on page 111. Compare it to the map in **Figure 6–20.** Are there any similarities among the biomes the hot spots belong to? Using what you know about biomes, are you surprised by what you've found? Explain your answer.

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6.4 Meeting Ecological Challenges

Key Questions

How does the average ecological footprint in America compare to the world's average?

How can ecology guide us toward a sustainable future?

Vocabulary

ecological footprint
ozone layer
aquaculture
global warming

Taking Notes

Compare/Contrast Table As you read, create a table comparing the challenges associated with the ozone layer, fisheries, and global climate. Note the problem observed, the causes identified, and the solutions implemented.

THINK ABOUT IT Every year, the EPA awards up to ten President's Environmental Youth Awards. Past winners have included an Eagle Scout from Massachusetts who encouraged people who fish to stop using lead weights that contaminate water and poison organisms, students from Washington State who reduced waste at their school and saved more than half a million dollars in the process, and a student from Florida who developed an outreach program to protect local sea turtles. What do these award winners have in common? They came up with ideas that protect the environment while satisfying both present and future needs. This kind of leadership is what will help us chart a new course for the future.

Ecological Footprints

How does the average ecological footprint in America compare to the world's average?

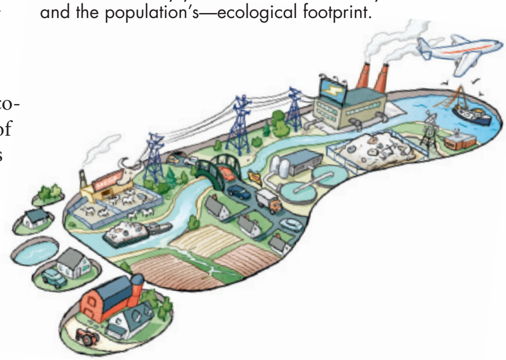
What is our impact on the biosphere today? To answer that question, think about the kind and amount of resources each of us uses. Ecologists refer to the human impact on the biosphere using a concept called the ecological footprint. The **ecological footprint** describes the total area of functioning land and water ecosystems needed both to provide the resources an individual or population uses and to absorb and make harmless the wastes that individual or population generates. Ecological footprints take into account the need to provide resources such as energy, food, water, and shelter, and to absorb such wastes as sewage and greenhouse gases. Ecologists use footprint calculations to estimate the biosphere's carrying capacity for humans. An artist's rendition of an ecological footprint is shown in **Figure 6–22.**

Footprint Limitations Ecologists talk about the ecological footprints of individuals, of countries, and of the world's population. Calculating actual numbers for ecological footprints, however, is complicated. The concept is so new that there is no universally accepted way to calculate footprint size. What's more, footprints give only a "snapshot" of the situation at a particular point in time.

VISUAL ANALOGY

ECOLOGICAL FOOTPRINTS

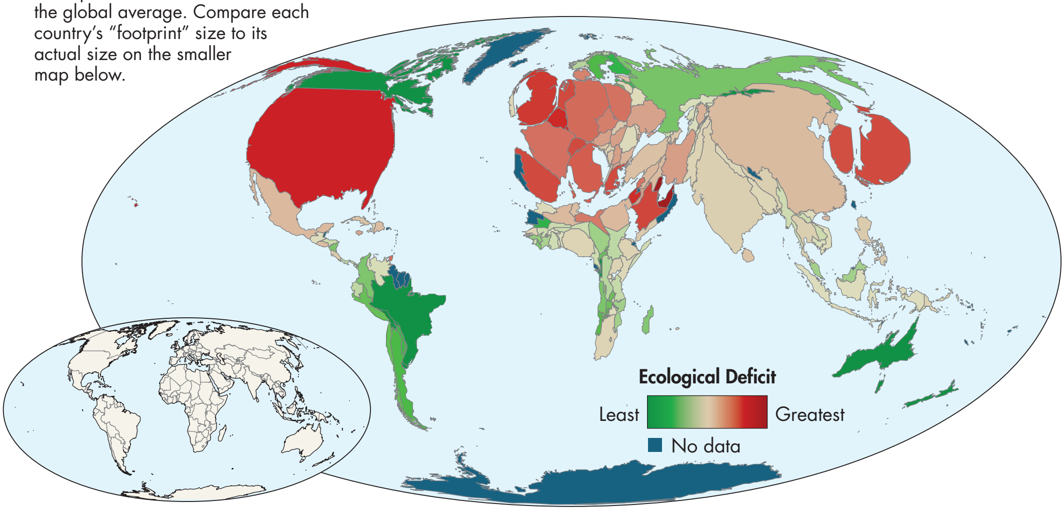
FIGURE 6–22 The food you eat, the miles you travel, and the electricity you use all contribute to your—and the population's—ecological footprint.



Comparing Footprints Although calculating *absolute* footprints is difficult, ecological footprints can be useful for making *comparisons* among different populations, as shown in **Figure 6–23.** **According to one data set, the average American has an ecological footprint over four times larger than the global average.** The per person use of resources in America is almost twice that in England, more than twice that in Japan, and almost six times that in China. To determine the ecological footprint of an entire country, researchers calculate the footprint for a typical citizen and then multiply that by the size of the population.

In Your Notebook *How have you contributed to your ecological footprint today? Give at least ten examples.*

FIGURE 6–23 Relative Footprints This world map shows each country in proportion to its ecological footprint. The United States has an ecological footprint about twice the world's average. By contrast, the African nation of Zambia has a footprint a little over one-fourth the global average. Compare each country's "footprint" size to its actual size on the smaller map below.



Ecology in Action

How can ecology guide us toward a sustainable future?

The future of the biosphere depends on our ecological footprints, global population growth, and technological development. Right now it's more common to hear stories of ecological challenges than successes. Given the size of those challenges, you might be tempted to give up, to feel that things are getting worse, and that there is nothing we can do about it. But ecological research, properly collected, analyzed, and applied, can help us make decisions that will produce profoundly positive effects on the human condition. The basic principles of ecology can guide us toward a sustainable future. **By (1) recognizing a problem in the environment, (2) researching that problem to determine its cause, and then (3) using scientific understanding to change our behavior, we can have a positive impact on the global environment.** The following case studies illustrate the importance of the steps.

Case Study #1: Atmospheric Ozone

Between 20 and 50 kilometers above Earth's surface, the atmosphere contains a relatively high concentration of ozone called the **ozone layer.** Ozone at ground level is a pollutant, but the natural ozone layer absorbs harmful ultraviolet (UV) radiation from sunlight. Overexposure to UV radiation is the main cause of sunburn. It also can cause cancer, damage eyes, and lower resistance to disease. And intense UV radiation can damage plants and algae. By absorbing UV light, the ozone layer serves as a global sunscreen.

The following is an ecological success story. Over four decades, society has recognized a problem, identified its cause, and cooperated internationally to address a global issue.

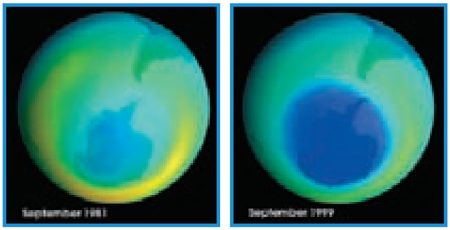


FIGURE 6–24 The Disappearing Ozone

FIGURE 6–25 CFC-Containing Refrigerators

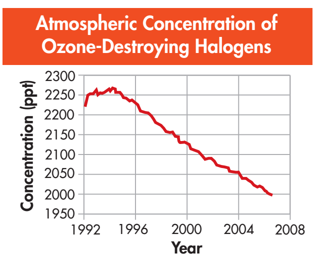


FIGURE 6–26 The Decline of CFCs

1 Recognizing a Problem: "Hole" in the Ozone Layer Beginning in the 1970s, satellite data revealed that the ozone concentration over Antarctica was dropping during the southern winter. An area of lower ozone concentration is commonly called an ozone hole. It isn't really a "hole" in the atmosphere, of course, but an area where little ozone is present. For several years after the ozone hole was first discovered, it grew larger and lasted longer each year. **Figure 6–24** shows the progression from 1981 to 1999. The darker blue color in the later image indicates that the ozone layer had thinned since 1981.

2 Researching the Cause: CFCs In 1974 a research team led by Mario Molina, F. Sherwood Rowland, and Paul J. Crutzen demonstrated that gases called chlorofluorocarbons (CFCs) could damage the ozone layer. This research earned the team a Nobel Prize in 1995. 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.

3 Changing Behavior: Regulation of CFCs Once the research on CFCs was published and accepted by the scientific community, the rest was up to policymakers—and in this case, their response was tremendous. Following the recommendations of ozone researchers, 191 countries signed a major agreement, the Montreal Protocol, which banned most uses of CFCs. Because CFCs can remain in the atmosphere for a century, their effects on the ozone layer are still visible. But ozone-destroying halogens from CFCs have been steadily decreasing since about 1994, as shown in **Figure 6–26,** evidence that the CFC ban has had positive long-term effects. In fact, current data predict that although the ozone hole will continue to fluctuate in size from year to year, it should disappear for good around the middle of this century.

Case Study #2: North Atlantic Fisheries

From 1950 to 1997, the annual world seafood catch grew from 19 million tons to more than 90 million tons. This growth led many to believe that the fish supply was an endless, renewable resource. However, recent dramatic declines in commercial fish populations have proved otherwise. This problem is one society is still working on.

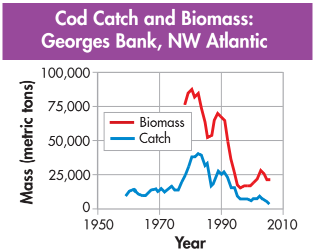


FIGURE 6–27 The Decline of Cod

FIGURE 6–28 Overfishing

FIGURE 6–29 Aquaculture

1 Recognizing a Problem: More Work, Fewer Fish The cod catch has been rising and falling over the last century. Some of that fluctuation has been due to natural variations in ocean ecosystems. But often, low fish catches resulted when boats started taking too many fish. From the 1950s through the 1970s, larger boats and high-tech fish-finding equipment made the fishing effort both more intense and more efficient. Catches rose for a time but then began falling. The difference this time, was that fish catches continued to fall despite the most intense fishing effort in history. As shown in **Figure 6–27,** the total mass of cod caught has decreased significantly since the 1980s because of the sharp decrease of cod biomass in the ocean. You can't catch what isn't there.

2 Researching the Cause: Overfishing Fishery ecologists gathered data including age structure and growth rates. Analysis of these data showed that fish populations were shrinking. By the 1990s, cod and haddock populations had dropped so low that researchers feared these fish might disappear for good. It has become clear that recent declines in fish catches were the result of overfishing, as seen in **Figure 6–28.** Fish were being caught faster than they could be replaced by reproduction. In other words, the death rates of commercial fish populations were exceeding birth rates.

3 Changing Behavior: Regulation of Fisheries The U.S. National Marine Fisheries Service used its best data to create guidelines for commercial fishing. The guidelines specified how many fish of what size could be caught in U.S. waters. In 1996, the Sustainable Fisheries Act closed certain areas to fishing until stocks recover. Other areas are closed seasonally to allow fish to breed and spawn. These regulations are helping some fish populations recover, but not all. **Aquaculture**—the farming of aquatic animals—offers a good alternative to commercial fishing with limited environmental damage if properly managed.

Overall, however, progress in restoring fish populations has been slow. International cooperation on fisheries has not been as good as it was with ozone. Huge fleets from other countries continue to fish the ocean waters outside U.S. territorial waters. Some are reluctant to accept conservation efforts because regulations that protect fish populations for the future cause job and income losses today. Of course, if fish stocks disappear, the result will be even more devastating to the fishing industry than temporary fishing bans. The challenge is to come up with sustainable practices that ensure the long-term health of fisheries with minimal short-term impact on the fishing industry. Exactly how to meet that challenge is still up for debate.

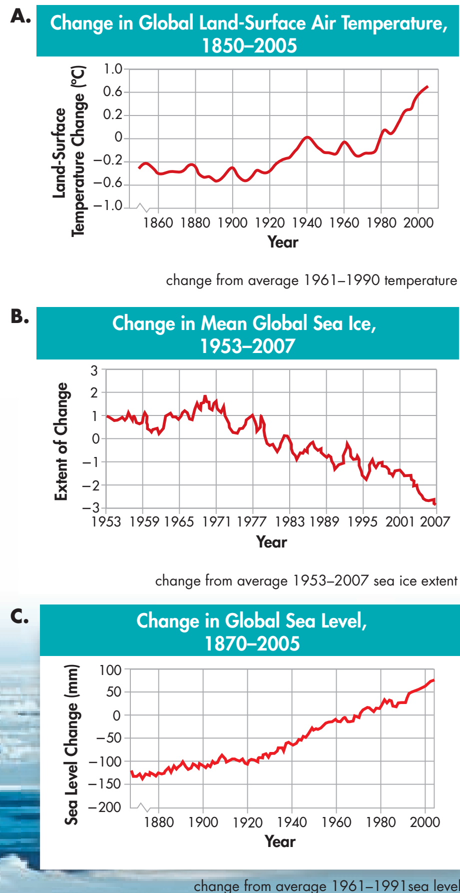
Case Study #3: Climate Change

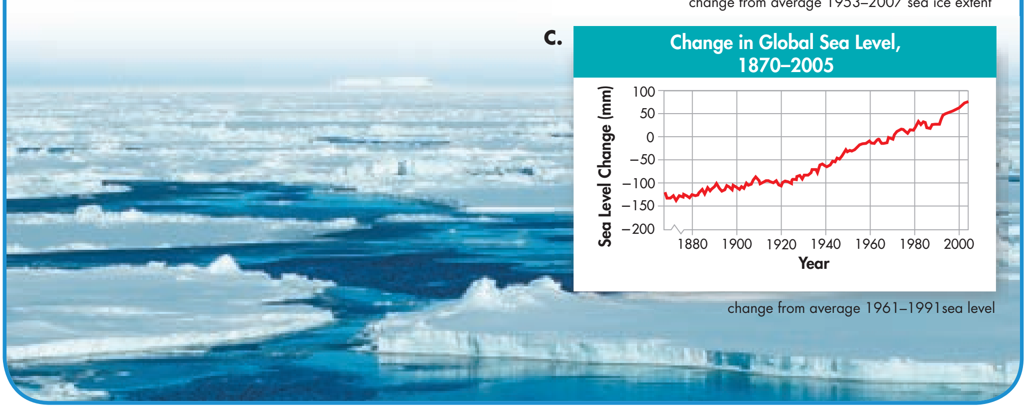
Global climate involves cycles of matter across the biosphere and everything modern humans do—from cutting and burning forests to manufacturing, driving cars, and generating electricity. The most reliable current information available on this subject comes from the 2007 report of the Intergovernmental Panel On Climate Change (IPCC). The IPCC is an international organization established in 1988 to provide the best possible scientific information on climate change. IPCC reports contain data and analyses that have been agreed upon and accepted by 2500 climate scientists from around the world and the governments participating in the study.

1 Recognizing a Problem: Global Warming The IPCC report confirms earlier observations that global temperatures are rising. This increase in average temperature is called **global warming.** Remember that winds and ocean currents, which are driven by differences in temperature across the biosphere, shape climate. Given this link between temperature and climate, it isn't surprising that the IPCC report discusses more than warming. The report also discusses climate change—changes in patterns of temperature, rainfall, and other physical environmental factors that can result from global warming. There are many lines of evidence, both physical and biological, that have contributed to our current understanding of the climate change issue.

- **Physical Evidence** Physical evidence of global warming comes from several sources. The graphs in **Figure 6–30,** taken from data in the 2007 IPCC report, show that Earth's temperatures are getting warmer, its sea ice is melting, and its sea levels are rising. Eleven of the twelve years between 1995 and 2006 were among the warmest years since temperature recording began in 1850. Between 1906 and 2005, Earth's average global temperature rose 0.74°C. The largest changes are occurring in and near the Arctic Circle. Average temperatures in Alaska, for example, increased 2.4°C over the last 50 years. Sea level has risen since 1961 at a rate of 1.8 mm each year. This increase is caused by warmer water expanding and by melting glaciers, ice caps, and polar ice sheets. Satellite data confirm that arctic sea ice, glaciers, and snow cover are decreasing.

FIGURE 6–30 A Warming Earth





• **Biological Evidence** Small changes in climate that humans scarcely notice can be important to other organisms. Remember that each organism's range is determined by factors like temperature, humidity, and rainfall. If those conditions change, the organisms can be affected. If temperature rises, for example, organisms would usually move toward cooler places away from the equator and from warm lowlands to cooler, higher altitudes. In addition, plant flowering and animal breeding are often cued by seasonal changes. If warming is occurring, these organisms should respond as though spring begins earlier.

The IPCC report summarizes data from 75 studies covering 1700 species of plants and animals. These data confirm that many species and communities are responding as though they are experiencing rising temperatures. The yellow-bellied marmot in **Figure 6–31,** for example, is coming out of hibernation over a month earlier than it used to.

FIGURE 6–31
Waking Up Too Early

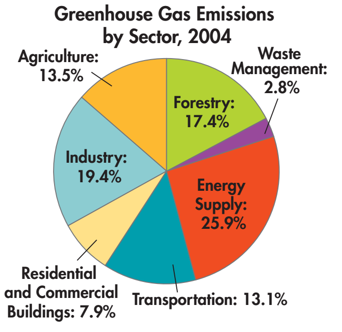
2 Researching the Cause: Models and Questions

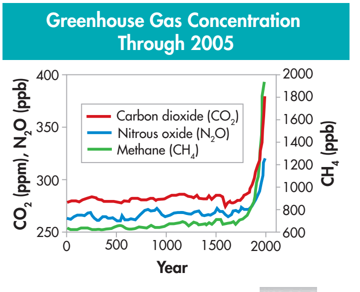
What is causing global warming? Earth's climate has changed often during its history. So researchers had to determine whether current warming is part of a natural cycle or whether it is caused by human activity or by astronomical and geological changes. As the IPCC report documents, concentrations of carbon dioxide and several other greenhouse gases have increased significantly over the last 200 years, as shown in **Figure 6–32.** Several kinds of data suggest this increase is due to the burning of fossil fuels, combined with the cutting and burning of forests worldwide. These activities add carbon dioxide to the atmosphere faster than the carbon cycle removes it. Most climate scientists agree that this added carbon dioxide is strengthening the natural greenhouse effect, causing the biosphere to retain more heat.

• **How Much Change?** How much warming is expected? For answers, researchers turn to computer models based on data. The models are complex and involve assumptions about climate and human activities. For these reasons, predictions are open to debate. The IPCC reports the result of six different models, which predict that average global temperatures will rise by the end of the twenty-first century from just under 2°C to as much as 6.4°C higher than they were in the year 2000.

• **Possible Effects of Climate Change** What does climate change mean? Some changes are likely to threaten ecosystems ranging from tundra and northern forests to coral reefs and the Amazon rain forest. The western United States is likely to get drier. The Sahara Desert, on the other hand, may become greener. Sea level may rise enough to flood some coastal ecosystems and human communities. And some models suggest that parts of North America may experience more droughts during the summer growing season.

FIGURE 6–32 Greenhouse Gases





Case Study #3: Climate Change (continued)

3 Changing Behavior: The Challenges Ahead You have seen how research has led to actions that are preserving the ozone layer and attempting to restore fisheries. In terms of global climate, great challenges lie ahead of us. Scientists have been saying for more than two decades that the world needs to recognize the importance of climate change and take steps to minimize further warming. The changes in behavior needed to cut back on greenhouse gas emissions will be major and will require input from economics and many other fields beyond biology. Some changes will rely on new technology for renewable energy and more efficient energy use. Because changing our use of fossil fuels and other behaviors will be difficult, researchers continue to gather data as they try to make more accurate models. In the meantime, we have begun to see the emergence of electric cars, recycled products, and green buildings.

Nations of the world have begun holding international climate summits, at which they attempt to work out agreements to protect the atmosphere and climate—both of which are truly global issues. As the world, and our own government, tries to work through these challenges, remember that the purpose of ecology is not to predict disaster or to prevent people from enjoying modern life. The world is our island of life. Hopefully, humanity can work toward a day when scientific information and human ingenuity help us reach the common goal of preserving the quality of life on Earth.

FIGURE 6–33 Little Changes, Big Results

6.4 Assessment

Review Key Concepts

1. a. **Review** What are ecological footprints?
   b. **Apply Concepts** What are the limitations of the ecological footprint model, and how can ecologists best use it?
2. a. **Review** Why is the ozone layer important to living things?
   b. **Explain** What are the major types of physical and biological evidence for climate change?
   c. **Propose a Solution** Suggest one solution for the fisheries problem. Your solution can be at the international, national, regional, or individual level. Explain how it would help, and what challenges you see in implementing it.

Apply the Big idea

Interdependence in Nature

3. Refer to the carbon cycle on page 83. Describe how extensive burning of fossil fuels is affecting other reservoirs of carbon in the biosphere.

Pre-Lab: Acid Rain and Seeds

Problem How does acid rain affect seed germination?

Materials white vinegar, distilled water, large test tubes, test-tube rack, glass-marking pencil, 25-mL graduated cylinder, food coloring, pipette, pH paper, dried beans, paper towels, zip-close plastic bags, stick-on labels, hand lens

Lab Manual Chapter 6 Lab

Skills Focus Design an Experiment, Organize Data, Measure, Graph

Connect to the Big idea Every organism alters its environment in some way. Elephants uproot trees, prairie dogs dig tunnels, and corals build reefs. But no other organism has as much impact on the global environment as humans. One of the ways that humans affect global ecology is by burning fossil fuels. The burning produces carbon dioxide, which can accumulate in the atmosphere and cause climate change. Other products react with water to form nitric and sulfuric acids. Rain that contains these acids can damage many things, including stone statues and growing plants. In this lab, you will investigate the effect of acid rain on seeds.

Background Questions

a. **Review** What does a pH scale measure?

b. **Review** Which solution is more acidic, one with a pH of 4.0 or one with a pH of 5.0, and why?

c. **Explain** Use the water cycle to trace the path from acids in water vapor to plants.

Pre-Lab Questions

Preview the procedure in the lab manual.

1. **Design an Experiment** What do you think the purpose is of adding food coloring to the vinegar in Part A?
2. **Infer** How will you know that a seed has germinated?
3. **Using Models** In this lab, what do the solutions represent?

BIOLOGY.com Search Chapter 6 GO

Visit Chapter 6 online to test yourself on chapter content and to find activities to help you learn.

Untamed Science Video The Untamed Science crew visits a zoo to learn about the important work that goes on behind the scenes.

Art in Motion View a short animation of biological magnification.

Art Review Review your understanding of the various threats to biodiversity with this activity.

Visual Analogy Compare human impact on the biosphere to a footprint in this activity.

Data Analysis Simulate data collection in order to compare two sites, and learn how to calculate a biodiversity index to quantify biodiversity.

6 Study Guide

Big idea Interdependence in Nature

Humans affect natural ecological processes through agriculture, urban development, and industry. But ecological science gives us strategies for sustainable development, ways we can protect the environment without slowing human progress.

6.1 A Changing Landscape

Humans affect regional and global environments through agriculture, development, and industry in ways that have an impact on the quality of Earth's natural resources, including soil, water, and the atmosphere.

Sustainable development provides for human needs while preserving the ecosystems that produce natural resources.

monoculture (155)
renewable resource (157)
nonrenewable resource (157)
sustainable development (157)

6.2 Using Resources Wisely

Healthy soil supports both agriculture and forestry.

It is possible to minimize soil erosion through careful management of both agriculture and forestry.

The primary sources of water pollution are industrial and agricultural chemicals, residential sewage, and nonpoint sources.

Common forms of air pollution include smog, acid rain, greenhouse gases, and particulates.

desertification (159)
deforestation (159)
pollutant (160)
biological magnification (161)
smog (163)
acid rain (164)

6.3 Biodiversity

Biodiversity's benefits to society include contributions to medicine and agriculture, and the provision of ecosystem goods and services.

Humans reduce biodiversity by altering habitats, hunting, introducing invasive species, releasing pollution into food webs, and contributing to climate change.

To conserve biodiversity, we must protect individual species, preserve habitats and ecosystems, and make certain that human neighbors of protected areas benefit from participating in conservation efforts.

biodiversity (166)
ecosystem diversity (166)
species diversity (166)
genetic diversity (166)
habitat fragmentation (168)
ecological hot spot (171)

6.4 Meeting Ecological Challenges

According to one data set, the average American has an ecological footprint over four times larger than the global average.

By (1) recognizing a problem in the environment, (2) researching that problem to determine its cause, and then (3) using scientific understanding to change our behavior we can have a positive impact on the global environment.

ecological footprint (173)
ozone layer (175)
aquaculture (176)
global warming (177)

Think Visually

Create a flowchart that shows the steps in the biological magnification of DDT. Your flowchart should show how DDT enters the food web and what effects it has on organisms.

6 Assessment

6.1 A Changing Landscape

Understand Key Concepts

1. Which of the following human activities has NOT had an important role in transforming the biosphere to date?
   a. agriculture
   b. industry
   c. development
   d. aquaculture

2. A resource that cannot easily be replenished by natural processes is called
   a. common.
   b. renewable.
   c. nonrenewable.
   d. conserved.

3. Describe how Hawaiian settlers negatively affected the islands after the 1700s.

4. Name four services that ecosystems provide for the biosphere.

Think Critically

5. **Propose a Solution** Devise guidelines your biology class can use to dispose of its nonlab trash in a safe, "environmentally friendly" way.

6. **Compare and Contrast** How are renewable and nonrenewable resources alike? How are they different?

7. **Form a Hypothesis** Monoculture fields are usually very large and homogeneous. Do you think this makes them more or less vulnerable to disease and pests? Explain.

6.2 Using Resources Wisely

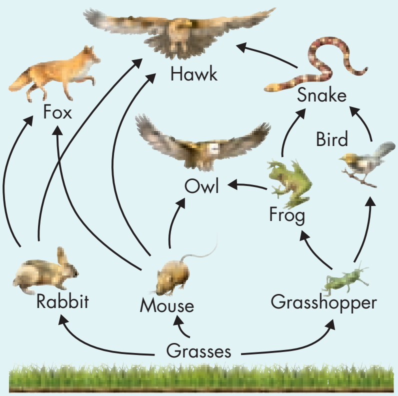
Understand Key Concepts

8. The conversion of a once soil-rich area to an area of little to no vegetation is called
   a. fragmentation.
   b. deforestation.
   c. desertification.
   d. acid rain.

9. The loss of fertile soils from an area through the action of water or wind is called
   a. acid rain.
   b. erosion.
   c. desertification.
   d. monoculture.

10. The concept of using natural resources at a rate that does not deplete them is called
    a. conservation.
    b. sustainable development.
    c. reforestation.
    d. successful use.

11. Examine the food web below. Which of the following organisms would accumulate the highest levels of a pesticide?
    a. hawk
    b. rabbit
    c. frog
    d. grasses



12. What is the difference between sustainable forestry and deforestation?

13. Identify some of the common sources of water pollution.

Think Critically

14. **Design an Experiment** Can covering soil with mulch or compost near the bases of plants help reduce soil erosion? Design an experiment to answer this question.

15. **Calculate** The concentration of a toxic chemical is magnified ten times at each trophic level. What will the concentration of the toxin be in organisms at the fifth trophic level if primary producers have concentrations of 40 parts per million?

16. **Infer** Why are lakes that have been affected by acid rain often clear and blue?

6.3 Biodiversity

Understand Key Concepts

17. A species that is introduced to an environment where it has not lived before is described as
a. native. **c.** threatened.
b. nonnative. **d.** predatory.

18. What is a habitat fragment?

19. List three different kinds of biodiversity that might be described in a given biome.

Think Critically

20. **Predict** How do you think the loss of biodiversity would adversely affect humans?

21. **Compare and Contrast** Explain the difference between species diversity and ecosystem diversity.

6.4 Meeting Ecological Challenges

Understand Key Concepts

22. The burning of fossil fuels is a direct cause of each the following EXCEPT
a. acid rain. **c.** smog.
b. global warming. **d.** the ozone hole.

23. The total impact a person has on the biosphere can be represented by his or her
a. contribution to climate change.
b. ecological footprint.
c. consumption of fossil fuel.
d. production of carbon dioxide.

24. Cite three examples of physical evidence for global warming.

25. What are some of the biological effects of climate change?

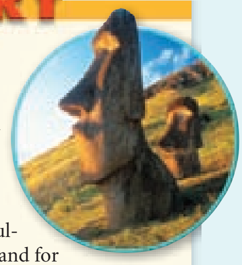
Think Critically

26. **Relate Cause and Effect** Why hasn't the ozone layer repaired itself fully since the widespread ban of CFCs in 1987?

27. **Apply Concepts** Describe some of the steps taken to counter the effects of overfishing cod in the North Atlantic. Why is overfishing such a complex environmental issue?

solve the CHAPTER MYSTERY

MOVING THE *MOAI*



Easter Island's environment was not as biologically diverse, and not as resistant to ecological damage, as the Hawaiian Islands. The Rapa Nui cut palm trees for agriculture, for logs to move *moai*, and for wood to make fishing canoes. They mismanaged cleared fields, so fertile topsoil washed away.

Meanwhile, rats they brought to the island became invasive. Hordes of the rodents destroyed palm seedlings, ate coconuts, and digested palm seeds before they could germinate. Hawaiians also brought rats to their islands, and rats did serious damage to native Hawaiian plants. But in Hawaii's more diverse forests, some plant species were not as hard hit by rats and survived.

The combination of human activity and the effects of an invasive species led to the destruction of virtually all of Easter Island's forests. This combination, along with the effects of a harsh climate, limited the island's carrying capacity for humans from then on.

1. **Relate Cause and Effect** How did the small size of the island (about half the size of Long Island, New York) affect the outcome of deforestation and pest invasion?

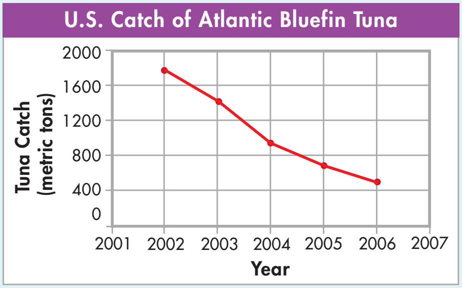
2. **Compare and Contrast** Gather information on differences in geography, climate, and biological diversity between Hawaii and Easter Island. How do you think those differences made the islands respond differently to human settlement?

3. **Connect to the Big idea** All human cultures throughout history have interacted with their environments. Do you think that global human society has any lessons to learn from the experiences of the Rapa Nui, the Hawaiians, and other historic cultures?

Connecting Concepts

Use Science Graphics

The graph shows the amount of bluefin tuna caught by the United States in the Atlantic Ocean between 2002 and 2006. Use the graph to answer questions 28 and 29.



28. Predict What trend would you expect to see in the annual catch from 2006 to 2007?

29. Propose a Solution What recommendations would you make to help the bluefin tuna population recover in the next decade or two?

Write About Science

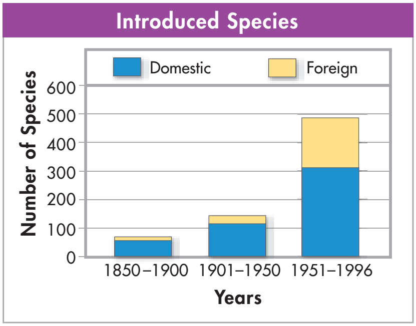
30. Explanation Write a paragraph explaining the value of wetlands to human societies. In your paragraph, include the concept of biodiversity as well as the role of wetlands in maintaining water resources for human use.

31. Assess the Big idea Why is it important to maintain species diversity in areas where humans live?

32. Assess the Big idea What environmental factors make high levels of biodiversity possible in most coastal waters? Refer to the discussion of abiotic and biotic factors in Chapter 4 if you need help answering this question.

Analyzing Data

The following graph shows the number of species introduced to new habitats in the United States in the last century. Some of the species were relocated to new habitats within the United States while others were imported from other countries.



33. Interpret Graphs Of domestic species and foreign species, which showed the greatest percentage increase between the 1901–1950 period and the 1951–1996 period?

a. domestic species
b. foreign species
c. Both increased the same amount.
d. There is not enough information to tell.

34. Draw Conclusions Which of the following statements about introduced species is most likely true based on the data shown?

a. Species introduced from foreign countries are always more harmful than species relocated within the country.
b. All introduced species are brought into this country by accident.
c. It is likely that the increase in the number of introduced species is due to increased global travel, trade, and communication.
d. The number of introduced species is likely to fall in the next half-century.

Standardized Test Prep

Multiple Choice

1. Which of the following statements about renewable resources is TRUE?
A They are only found in tropical climates.
B They can never be depleted.
C They are replaceable by natural means.
D They regenerate very quickly.

2. Which of the following is a nonrenewable resource?
A wind
B fresh water
C coal
D topsoil

3. Which of the following is NOT a direct effect of deforestation?
A decreased productivity of the ecosystem
B soil erosion
C biological magnification
D habitat destruction

4. The total variety of organisms in the biosphere is called
A biodiversity.
B species diversity.
C ecosystem diversity.
D genetic diversity.

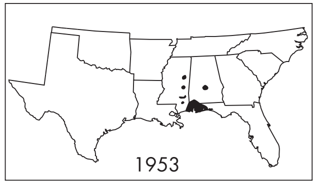
5. Ozone is made up of
A hydrogen.
B oxygen.
C nitrogen.
D chlorine.

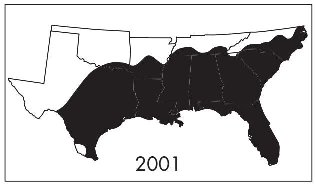
6. Ozone depletion in the atmosphere has been caused by
A monoculture.
B CFCs.
C suburban sprawl.
D soil erosion.

7. In a food chain, concentrations of harmful substances increase in higher trophic levels in a process is known as
A biological magnification.
B genetic drift.
C biological succession.
D pesticide resistance.

Questions 8 and 9

Fire ants first arrived in the United States in 1918, probably on a ship traveling from South America to Alabama. The maps below show the geographic location of the U.S. fire ant population in 1953 and 2001.





8. Which of the following statements about fire ants in the United States is TRUE?
A They reproduce slowly.
B They are a native species of the United States.
C They are an invasive species.
D They do not compete with other ant species.

9. By 2010, fire ants are MOST likely to
A have spread to a larger area.
B have reached their carrying capacity.
C die out.
D return to South America.

Open-Response

10. Describe how ecologists use the ecological footprint concept.

If You Have Trouble With . . .

Question	1	2	3	4	5	6	7	8	9	10
See Lesson	6.1	6.2	6.2	6.3	6.2	6.4	6.2	6.3	6.3	6.4

Unit Project

Development Debate

A large company wants to build a new factory on your town's wetlands. Many people in the town are opposed to the idea, claiming it will disturb the local ecosystem and cause problems for residents. Others support the development, arguing that the new factory will bring jobs and money into the town. Representatives have been called in to debate the issue before the town council.

Your Task Take on one of the stakeholder roles listed below. Find evidence to support that point of view and debate the issue in class. The roles are

- Conservation ecologist
- CEO of the company
- Town mayor who supports the development
- Resident of the town who lives next to the wetlands

Be sure to

- justify your arguments with credible information.
- present your arguments in a clear and convincing manner.

Reflection Questions

1. Score your performance using the rubric below. What score did you give yourself?

2. What did you do well in this project?

3. What about your performance needs improvement?

4. After hearing various sides of the argument, meet with a partner and discuss which side you agree with the most. Justify your opinion.

Assessment Rubric

Score	Evidence Provided	Quality of Performance
4	Student justifies his/her argument with sophisticated and highly credible information.	Ideas are presented in a highly convincing and clear manner. Student shows a deep understanding of the issues involved.
3	Student justifies his/her argument with logical and credible information.	Ideas are presented in an effective and clear manner. Student shows a solid understanding of the issues involved.
2	Student provides some credible information, but other points are weak or inaccurate.	Some ideas are presented in an unclear manner. Student shows a limited understanding of the issues involved.
1	Student provides mostly illogical and invalid evidence to support his/her argument.	Most ideas are presented in an unclear manner. Student shows a very limited understanding of the issues involved.