16

Biological Resources

Wolfgang Kaehler/LightRocket/Getty Images

Tiger cub in Bandhavgarh National Park, India.

The tiger, the largest member of the cat family, lives in India, Indonesia, Thailand, Russia, and a few other Asian countries. Although a large, powerful predator, the tiger is in danger of becoming extinct. During the past century, the areas in which wild tigers are found have declined to only 7% of the tiger's historical range. About 3200 tigers are left in the wild, down from an estimated 100,000 a century ago.

More wild tigers—more than half the world's tiger population—live in small fragments of habitat in India than anywhere else. India has hundreds of tiger sanctuaries, including the Bandhavgarh National Park (see photograph). However, in 2005 park rangers discovered that all 20 tigers in India's Sariska Tiger Reserve had disappeared. (A few tigers have since been reintroduced to the reserve.) Tiger populations in Bandhavgarh and other Indian reserves are also declining precipitously.

Although tigers are protected by law, they are illegally hunted to meet a growing demand for tiger skins, bones, organs, and meat. In traditional Asian medicine, tiger bone wine, made by steeping tiger bones in alcohol for an extended period, is thought to be a potent health tonic. Similarly, tiger penis soup is thought to improve sexual capacity, and tiger eyes to prevent convulsions.

Many of the laws passed against tiger poaching and smuggling of tiger skins and body parts are not enforced. The number of patrols guarding against poachers in tiger reserves is inadequate, and few poachers are actually caught. Instead, poachers have in many cases assaulted or even murdered reserve guards. When poachers are caught and prosecuted, the fines they receive are too small to act as a deterrent.

Another factor in tiger decline is loss of habitat. As the human population continues to grow, more wild land is altered for human needs, leaving tiger habitat increasingly fragmented. Humans also hunt the same animals that tigers do, and existing tigers have fewer potential prey in their fragmented habitats.

Clearly, a concerted commitment is needed at local, national, and international levels if wild tiger populations are to be saved. Like many environmental problems, the challenge of tiger conservation is complex: Science, economics, social standards, cultural beliefs and traditions, political factors, human population growth, and national and international policies can all influence the fate of wild tiger populations.

In this chapter we first examine the importance of all forms of life, and then we consider extinction, which is an increasing threat to tigers and many other organisms. Finally, we explore how to preserve biological resources and save at least some endangered species from disappearing forever.

In Your Own Backyard...

Visit www.fws.gov/endangered/ and identify your state to search for endangered species located near you. Scroll down to see all of them. How many endangered animal species are there? How many plants?

Biological Diversity

LEARNING OBJECTIVES

- Define *biological diversity* and distinguish among genetic diversity, species richness, and ecosystem diversity.
- Describe several important ecosystem services provided by biological diversity.

A **species** is a group of more or less distinct organisms that are capable of interbreeding with one another in nature to produce fertile offspring but do not interbreed with other organisms. We do not know exactly how many species exist. In fact, biologists now realize how little we know about Earth's diverse organisms. Scientists estimate there may be as few as 5 million or as many as 100 million species. According to the International Union for Conservation of Nature (IUCN), about 1.7 million species have been scientifically named and described to date, including nearly 310,000 plant species, 65,000 vertebrate animal species, and 1 million insect species. About 10,000 new species are identified each year (**Figure 16.1**).

The variation among organisms is referred to as **biological diversity** or **biodiversity,** but the concept includes much more than simply the number of species, which is known as **species richness.** Biological diversity occurs at all levels of biological organization, from populations to ecosystems. It takes into account **genetic diversity,** the genetic variety *within* all populations of that species. Biological diversity also includes **ecosystem diversity**, the variety of ecosystems found on Earth: the forests, prairies, deserts, coral reefs, lakes, coastal estuaries, and other ecosystems of our planet. Ecosystem diversity also encompasses the variety of interactions among organisms in natural communities. For example, a forest community with its trees, shrubs, vines, herbs, insects, worms, vertebrate animals, fungi, bacteria, and other microorganisms has greater ecosystem diversity than a wheat field.

ological diversity ie number, variety, ariability of Earth's rganisms; consists hree components: c diversity, species ss, and ecosystem diversity.

Figure 16.1 A newly discovered species. This wallaby (*Dorcopsulus* sp. nov.) is the smallest kangaroo known in the world. Discovered in Indonesia, it is 60 cm (about 2 ft) long. Conservation International announced the discovery in 2010.

WHY WE NEED ORGANISMS

Humans depend on the contributions of thousands of species for their survival. In traditional (nonmodern) societies, these contributions are direct: Plants, animals, and other organisms are the sources of food, clothing, and shelter. In industrialized societies, most people do not hunt for their morning breakfasts or cut down trees for their shelter and firewood. Nevertheless, we still depend on organisms.

Although all societies make use of many kinds of plants, animals, fungi, and microorganisms, most species have not been evaluated for their potential usefulness. At least 250,000 of the 310,000 known plant species have not been assessed for their industrial, medicinal, or agricultural potential. The same is true of most of the millions of microorganisms, fungi, and animals.

Most people do not think of insects as an important biological resource, but insects are instrumental in several important ecological and agricultural processes, including pollination of crops, weed control, and insect pest control. In addition, many insects produce unique chemicals that may have important applications for human society. Bacteria and fungi provide us with foods, antibiotics, and other medicines, as well as important biological processes such as nitrogen fixation (see Chapter 4). Biological diversity represents a rich, untapped resource for future uses and benefits, and many as-yet-unknown species may someday provide us with products. A reduction in biological diversity decreases this treasure prematurely and permanently.

Ecosystem Services and Species Richness The living world is a complex system. Each ecosystem is composed of many separate parts, the functions of which are organized and integrated to maintain the ecosystem's overall performance. The activities of all organisms are interrelated; we are linked and dependent on one another and on the physical environment, often in subtle ways. When one species declines, other species linked to it may decline or increase in number.

Consider, for example, the role of alligators in the environment (**Figure 16.2**). The American alligator helps maintain populations of smaller fishes by eating the gar, a fish that preys on them. Alligators dig underwater holes that other aquatic organisms use during droughts, when the water level is low. The nest mounds they build are enlarged each year and eventually form small islands colonized by trees and other plants. In turn, the trees on these islands support heron and egret populations. The alligator habitat is maintained in part by underwater "gator trails," which help clear out aquatic vegetation that might eventually form a marsh.

Plants, animals, fungi, and microorganisms are instrumental in many environmental processes essential to human existence. Forests are not just a potential source of lumber; forests provide watersheds from which we obtain fresh water, control the number and severity of local floods, and reduce soil erosion. (See the Chapter 14 opener for a vivid example of the consequences of erosion, a landslide in Washington State.) Many flowering plant species depend on insects to transfer pollen for reproduction. Animals, fungi, and microorganisms help keep the populations of various species in check so that the numbers of one species do not

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Figure 16.2 Role of alligators in the environment. The American alligator (*Alligator mississippiensis*) plays an integral, but often subtle, role in its natural ecosystem. Photographed in the Everglades.

increase enough to damage the stability of the entire ecosystem. Soil dwellers, from earthworms to bacteria, develop and maintain soil fertility for plants. Bacteria and fungi perform the crucial task of decomposition, which allows nutrients to cycle in the ecosystem. All these processes are **ecosystem services**, important environmental benefits that ecosystems provide to people, such as clean air to breathe, clean water to drink, and fertile soil in which to grow crops. Ecosystem services maintain the living world, including human societies, and we are completely dependent on them. (Table 5.1 summarizes some important ecosystem services.)

The loss of only a few species from an ecosystem endangers the other organisms in unpredictable ways. Just as a car runs less smoothly if some parts are missing, the removal of species from a community makes an ecosystem run less smoothly. If enough species are removed, the entire ecosystem will change. Species richness within an ecosystem provides the ecosystem with resilience, that is, the ability to recover from environmental changes or disasters (see the discussion of species richness and community stability in Chapter 5).

Genetic Reserves The maintenance of a broad genetic base is critical for each species' long-term health and survival. Consider economically important crop plants. During the 20th century, plant scientists developed genetically uniform, high-yielding varieties of important food crops such as wheat. It quickly became apparent, however, that genetic uniformity resulted in increased susceptibility to pests and disease.

By crossing the "superstrains" with more genetically diverse relatives, disease and pest resistance can be reintroduced into such plants. A corn blight fungus that ruined the corn crop in the United States in 1970 was brought under control by crossing the cultivated, highly uniform U.S. corn varieties with genetically diverse ancestral varieties from Mexico. When some of the genes from Mexican corn were incorporated into the U.S. varieties, the U.S. strains became resistant to the corn blight fungus. (The global decline in domesticated plant and animal varieties is discussed in Chapter 18.)

Scientific Importance of Genetic Diversity *Genetic engineering*, the incorporation of genes from one organism into a different species (see Figure 18.11), makes it possible to use the genetic resources of organisms on a wide scale. The gene for human insulin, for example, was engineered into bacteria. These bacteria subsequently become tiny chemical factories, manufacturing at a relatively low cost the insulin required in large amounts by diabetics. Though not without controversy, genetic engineering, available since the mid-1970s, has provided new vaccines, more productive farm animals, and agricultural plants with greater disease resistance.

Although we have the skills to transfer genes from one organism to another, we do not have the ability to *make* genes that encode for specific traits. Genetic engineering depends on the broad base of genetic diversity from which it obtains genes. It has taken hundreds of millions of years for **evolution** to produce the genetic diversity found in organisms living on our planet today. This diversity may hold solutions to today's problems and to future problems we have not begun to imagine. We would be unwise to allow such an important part of our heritage to disappear.

Medicinal, Agricultural, and Industrial Importance of Organisms The genetic resources of organisms are vitally important to the pharmaceutical industry, which incorporates into its medicines many hundreds of chemicals derived from organisms. From extracts of cherry and horehound for cough medicines to certain ingredients of periwinkle and mayapple for cancer therapy, derivatives of plants play important roles in the treatment of illness and disease (**Figure 16.3**). Many of the natural products taken directly from marine organisms, such as tunicates, red algae, mollusks, corals, and sponges, are promising anticancer or antiviral drugs. The AIDS (acquired immune

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Figure 16.3 Medicinal value of the rosy periwinkle. The rosy periwinkle (*Catharanthus roseus*) produces chemicals effective against certain cancers. Drugs (e.g., Vincristine) from the rosy periwinkle have increased the chance of surviving childhood leukemia from about 5% to more than 95%.

deficiency syndrome) drug AZT (azidothymidine), for example, is a synthetic derivative of a compound from a sponge. The 20 best-selling prescription drugs in the United States are either natural products, natural products that are slightly modified chemically, or synthetic drugs whose chemical structures were originally obtained from organisms.

The agricultural importance of plants and animals is indisputable, because we must eat to survive. However, the kinds of foods we eat are limited compared with the total number of edible species. Many species that are nutritionally superior to our common foods probably exist. Winged beans are a tropical legume from Southeast Asia and Papua New Guinea. Because the seeds of the winged bean contain large quantities of protein and oil, they may be the tropical equivalent of soybeans. Almost all parts of the plant are edible, from the young, green fruits to the starchy storage roots.

Modern industrial technology depends on a broad range of products from organisms. Plants supply oils and lubricants, perfumes and fragrances, dyes, paper, lumber, waxes, rubber and other elastic latexes, resins, poisons, cork, and fibers. Animals provide wool, silk, fur, leather, lubricants, waxes, and transportation, and they are important in medical research.

Insects secrete a large assortment of chemicals that represent a wealth of potential products. Certain beetles produce steroids with birth-control potential, fireflies produce a compound that may be useful in treating viral infections, and some fly species show promise as a source of new antibiotics. Centipedes secrete a fungicide that could help protect crops. Because biologists estimate that perhaps 90% of all insects have not yet been identified, insects represent an important potential biological resource.

Aesthetic, Ethical, and Spiritual Value of Organisms Organisms not only contribute to human survival and physical comfort; they also provide mental health benefits, recreation, inspiration, and spiritual solace. Our natural world is a thing of beauty largely because of the diversity of living forms found in it. Artists have attempted to capture this beauty in drawings, paintings, sculpture, and photography; poets, writers, architects, and musicians have created works reflecting and celebrating the natural world. Several studies of people living in urban environments have indicated that parks and green spaces promote psychological well-being, including the ability to concentrate better and to lower levels of anxiety.

The strongest ethical consideration involving the value of organisms is how humans perceive themselves in relation to other species. Traditionally, many human cultures have viewed themselves as superior beings, subduing and exploiting other forms of life for their benefit. An alternative view is that organisms have intrinsic value in and of themselves and that, as stewards of the life-forms on Earth, humans should watch over and protect their existence (see Chapter 2 for a discussion of *environmental ethics*).

REVIEW

1. What is biological diversity?
2. What are three examples of ecosystem services provided by biological diversity?

Extinction and Species Endangerment

LEARNING OBJECTIVES

- Define *extinction* and distinguish between background extinction and mass extinction.
- Contrast threatened and endangered species, and list four characteristics common to many endangered species.
- Define *biodiversity hotspots* and explain where most of the world's biodiversity hotspots are located.
- Describe four human causes of species endangerment and extinction, and explain which cause is the most important.
- Explain how invasive species endanger native species.

Extinction, the death of a life-form, occurs when the last individual member of a species dies. Extinction is an irreversible loss: Once a species is extinct, it will never reappear. Biological extinction appears to be the eventual fate of all species, much as death is the eventual fate of all individuals. Biologists estimate that for every 2000 species that have ever lived, 1999 of them are extinct today.

extinction The death of the last individual of a species.

During the time span in which organisms have occupied Earth, a continuous, low-level extinction of species, or **background extinction**, has occurred. At certain periods in Earth's history, maybe five or six times, there has been a second kind of extinction, **mass extinction**, in which numerous species disappeared during a relatively short period of geologic time. The course of a mass extinction episode may have taken millions of years, but that is a short time compared with the time that life has existed on this planet, which is estimated at about 3.5 billion years.

The causes of past mass extinctions are not well understood, but biological and environmental factors were probably involved. A major climate change could have triggered the mass extinction of species. Marine organisms are particularly vulnerable to temperature changes; if Earth's temperature changed just a few degrees, it is likely that many marine species would become extinct. It is possible that mass extinctions of the past were triggered by catastrophes, such as the collision of Earth with a large asteroid or comet. The impact could have forced massive quantities of dust into the atmosphere, blocking the sun's rays and cooling the planet.

Although extinction is a natural biological process, it is greatly accelerated by human activities. The burgeoning human population has spread into almost all areas of Earth. Whenever humans invade an area, the habitats of many organisms are disrupted or destroyed, which contributes to their extinction.

Currently, Earth's biological diversity is disappearing at an unprecedented rate (**Figure 16.4**). Conservation biologists estimate that species are presently becoming extinct at a rate of 100 to 1000 times the natural rate of background extinctions. For example, IUCN listed nearly 20,000 species as threatened with extinction in 2012, including 13% of birds, 25% of mammals, and 41% of amphibians. About 9400 species of plants are currently threatened with extinction (see You Can Make a Difference: Addressing Declining Biological Diversity).

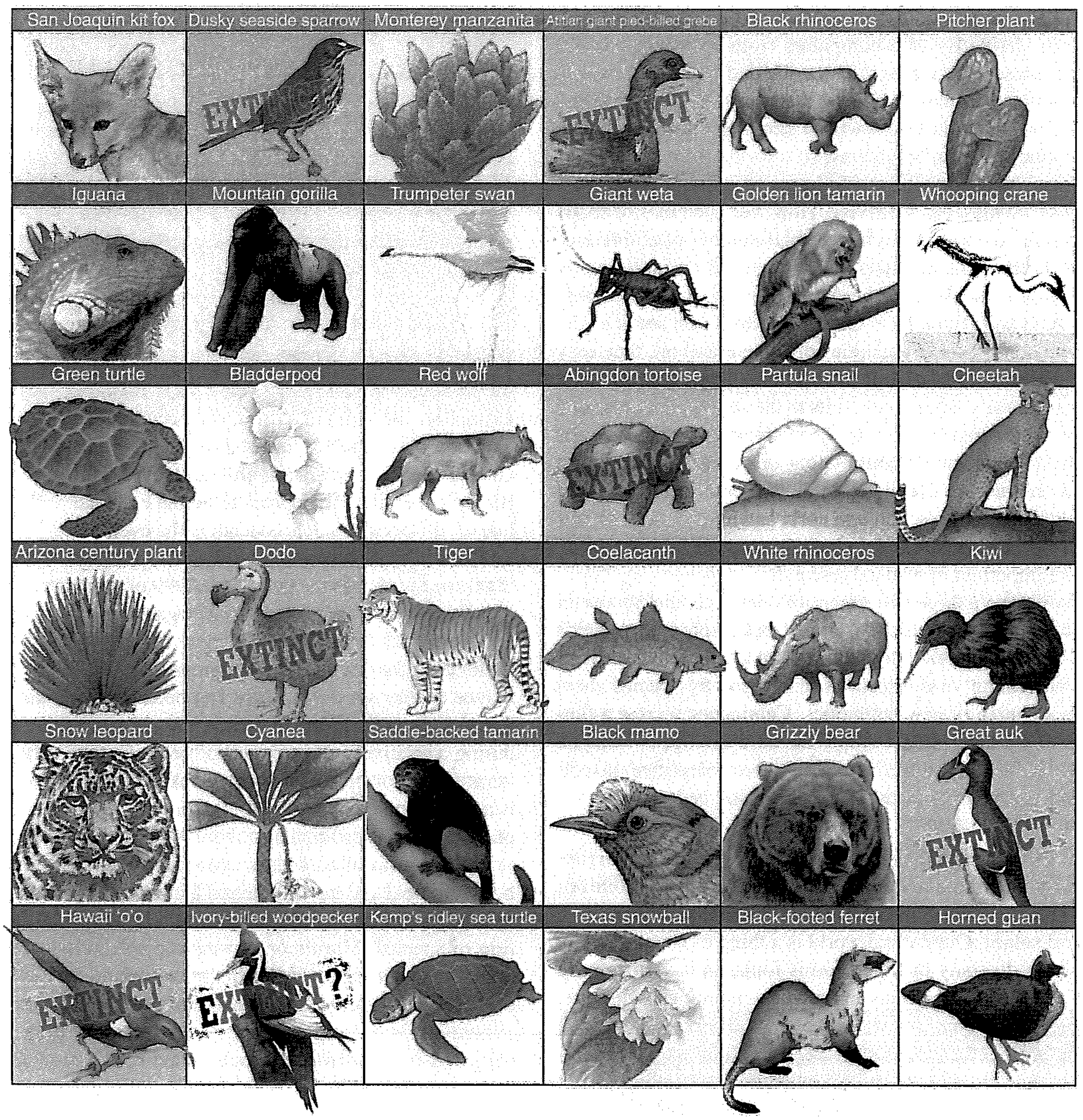


Figure 16.4 **Representative endangered or extinct species.** Officials at the U.S. Fish and Wildlife Service estimate that more than 500 U.S. species have gone extinct during the past 200 years. Of these, roughly 250 have become extinct since 1980.

ENDANGERED AND THREATENED SPECIES

The legal definition of an **endangered species**, as stipulated in the Endangered Species Act, is a species in imminent danger of extinction throughout all or a significant portion of its range. (The area in which a particular species is found is its **range**.) A species is endangered when its numbers are so severely reduced that it is in danger of becoming extinct without human intervention.

endangered species A species that faces threats that may cause it to become extinct within a short period.

A species is defined as **threatened** when extinction is less imminent but its population is quite low. The legal definition of a threatened species is a species likely to become endangered in the foreseeable future, throughout all or a significant portion of its range.

threatened species A species whose population has declined to the point that it may be at risk of extinction.

Endangered and threatened species represent a decline in biological diversity because as their numbers decrease, their genetic variability is severely diminished. Long-term survival and evolution depend on genetic diversity, so a decline in genetic diversity adds to the risk of extinction for endangered and threatened species, as compared to species that have greater genetic variability.

YOU CAN MAKE A DIFFERENCE

Addressing Declining Biological Diversity

children and grandchildren are faced with iting a biologically impoverished world, people dedicated to preserving our bio- al heritage can reverse the trend toward ction. You do not have to be a biologist iake a contribution; some of the most ırtant contributions come from outside cientific arena. Following is a partial list of ns that would help maintain the biologi- iversity that is our heritage:

political commitment to protect organ- ns is necessary because no immediate short-term economic benefit is obtained om conserving species. This commit- ent must take place at all levels, from cal to international. Lawmaking will not isure the protection of organisms without rong public support. Increasing public vareness of the importance of biological versity is critical. As individuals, we can lucate ourselves on biodiversity issues of ırticular importance in our regions.

oviding publicity on species conservation sues costs money. Private funds raised organizations such as the Sierra Club, e Nature Conservancy, and the World ldlife Fund support such endeavors, but ore money is needed. As individuals, we can join and actively support conservation organizations.

3. Before an endangered species can be saved, its numbers, range, ecology, biological nature, and vulnerability to environmental changes must be determined. Basic research provides this information. We cannot preserve a given species effectively until we know how large to make a protected habitat and what features are essential in its design. As individuals, we can inform state and national politicians of our desire to have conservation research funded with tax dollars.
4. A worldwide system of protected parks and reserves that includes every major ecosystem must be established. The protected land would provide other benefits in addition to the preservation of biological diversity. It would safeguard the watersheds that supply water, serve as a renewable source of important biological products in areas with multiple uses, and provide people with unspoiled lands for aesthetic and recreational enjoyment. As individuals, we can help establish parks by writing to national lawmakers.
5. Establishing protected areas will not prevent biological impoverishment if we continue to pollute the planet, because it is impossible to protect parks and refuges from threats such as global climate change. Strong steps must be taken to curb the practice of dumping CO_2 and other pollutants into the air, soil, and water—for human health and well-being, and for the well-being of species so important to ecosystem stability. Specific recommendations on how we as individuals can reduce pollution are discussed in Chapters 19 through 23.
6. Developing nations in the tropics, the repositories of most of Earth's genetic diversity, do not have much money to spend on conservation. Their governments are consumed with human problems such as overpopulation, disease, and foreign debts. Participating in ecotourism is one way to help such countries appreciate the importance of the biological resources they possess. Ecotourists pay to visit natural environments and view native species. Well-executed ecotourism conserves natural areas and improves the well-being of local people. Additionally, developed nations can provide economic incentives to developing countries by forgiving or reducing their debts in exchange for their support of local conservation efforts, including the protection of endangered species.

The choices we make and the policies we support at all levels of government can impact ecosystems and species around the world.

Characteristics of Endangered Species Many endangered species share certain characteristics that seem to have made them more vulnerable to extinction. These characteristics include having an extremely small (localized) range; requiring a large territory; living on islands; having low reproductive success, often the result of a small population size or low reproductive rates; needing specialized breeding areas; and having specialized feeding habits.

Many endangered species have a limited natural range, which makes them particularly prone to extinction if their habitat is altered. The Tiburon mariposa lily consists of a single population growing on a hilltop near San Francisco. Development of that area would almost certainly cause the extinction of this species.

Species that require extremely large territories to survive—often because they are tertiary consumers at the top of the food web—may be threatened with extinction when all or part of their territory is modified by human activity. The California condor, a scavenger bird that lives off carrion and requires a large, undisturbed territory of hundreds of square kilometers in which to find adequate food, is slowly recovering from the brink of extinction. In 1983, the California condor population reached a low of 22 birds, and from 1987 to 1992, it was no longer found in nature (**Figure 16.5**). A program to reintroduce zoo-bred California

Frans Lanting / MINT Images / Science Source

Figure 16.5 California condor. California condors (*Gymnogyps californianus*), which have up to a 3-meter (10-foot) wingspan, are critically endangered largely because development has reduced the size of their wilderness habitat. Condors also face other environmental threats. Photographed in Big Sur, California.

condors into the wild began in 1992. By the end of 2013, there were 412 condors, more than half of them living in the wild in California (including Pinnacles National Park; see Chapter 17) and adjacent areas in Mexico and Arizona. The condor story is not an unqualified success, however, because they have yet to become a self-sustaining population that replaces its numbers without augmentation by captive breeding. Currently, the greatest threat to the condor's recovery is lead toxicity; condors ingest lead pellets when they eat prey shot by hunters.

Many species **endemic** to certain islands (i.e., they are not found anywhere else in the world) are endangered. These organisms often have small populations that cannot be replaced by immigration if their numbers are destroyed. Because they evolved in isolation from competitors, predators, and disease organisms, island species have few defenses when such organisms are introduced, usually by humans. It is not surprising that of the 171 bird species that have become extinct in the past few centuries, 155 of them lived on islands.

In ecological terms, *island* refers not only to any landmass surrounded by water but also to any isolated habitat surrounded by an expanse of unsuitable territory. Accordingly, a small patch of forest surrounded by agricultural and suburban lands is considered an island. **Habitat fragmentation**, the breakup of large areas of habitat into small, isolated patches (i.e., islands), is a major threat to the long-term survival of many species. (National parks are discussed as islands in Chapter 17.) For a species to survive, its members must be present within their range in large enough numbers for males and females to mate. The minimum population density and size that ensure reproductive success vary from one type of organism to another. For all organisms, if the population density and size fall below a critical minimum level, the population declines, becoming susceptible to extinction.

Endangered species often share other characteristics. Some have low reproductive rates. The female blue whale produces a single calf every other year, and no more than 6% of swamp pinks, an endangered species of small flowering plant, produce flowers in a given year (**Figure 16.6**). Some endangered species breed only in specialized areas; the Kemp's ridley sea turtle, for example, lays its eggs on a single beach in Mexico.

Highly specialized feeding habits may endanger a species. In nature, the giant panda eats only bamboo. Periodically, all the bamboo plants in a given area flower and die; when this occurs, panda populations face starvation. Like many other endangered species, giant pandas are also endangered because their habitat has been fragmented into small islands. China's approximately 1600 wild giant pandas live in isolated habitats that occupy a small fraction of their historical range. China, in partnership with the World Wildlife Fund (WWF), has established roughly 40 panda reserves.

Jeffrey Lepore/Science Source

Figure 16.6 The swamp pink. This endangered species lives in the boggy areas of the eastern United States. Photographed in Killens Pond State Park, Delaware. Why might this species be particularly vulnerable to climate change? (*Hint:* How might its habitat change as the climate changes?)

As serious as declining biological diversity is in the United States, it is even more serious abroad, particularly in tropical rain forests. Although tropical rain forests—found in South and Central America, central Africa, and Southeast Asia—cover only 7% of Earth's surface, as many as 50% of all species inhabit them. Using remote-sensing surveys, scientists have determined that approximately 1% of tropical rain forests are being cleared or severely degraded each year. The forests are making way for human settlements, banana and oil palm plantations, oil and mineral explorations, and other human activities. (Tropical rain forests are discussed in Chapters 6 and 17.)

WHERE IS DECLINING BIOLOGICAL DIVERSITY THE GREATEST PROBLEM?

Declining biological diversity is a concern throughout the United States, but it is most serious in the states of Hawaii (where 63% of species are at risk) and California (where about 29% of species are at risk). Hawaii has lost hundreds of species and has more species listed as endangered than any other state. At least two-thirds of Hawaii's native forests are gone.

Earth's Biodiversity Hotspots In 1988, ecologist **Norman Myers** of Oxford University coined the term **biodiversity hotspots.** In 2000, using plants as their criteria, Myers and ecologists at Conservation International identified 25 biodiversity hotspots around the world. A substantive reanalysis has now delineated a total of 34 hotspots (**Figure 16.7**). More than 50% of all species of vascular plants live within the hotspots. An estimated 42% of the world's terrestrial vertebrate species and 29% of its freshwater fish are endemic to these regions. Many humans—nearly 20% of the world's population—live in the hotspots. Many hotspots are tropical forests, 10 are mostly or solely islands, and others are isolated by deserts or mountain ranges.

biodiversity hotspots Relatively small areas of land that contain an exceptional number of endemic species and are at high risk from human activities.

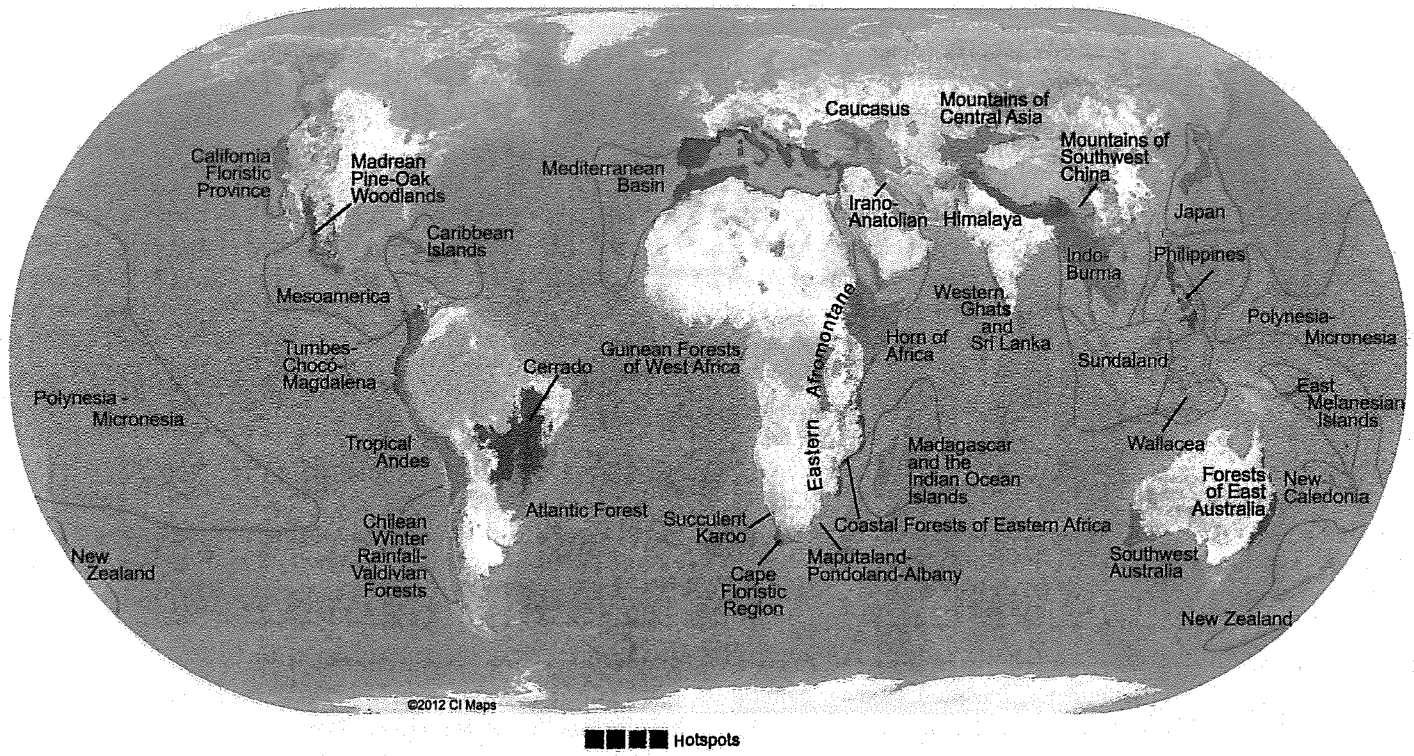


Figure 16.7 Biodiversity hotspots. These 34 hotspots, which are rich in endemic species, are at great risk from human activities. (Map by Conservation International)

Many biologists recommend that conservation planners focus on preserving land in these hotspots to reduce the mass extinction of species currently under way. Not all biologists agree. Some critics think that concentrating most of our efforts on the 34 biodiversity hotspots causes us to neglect species living in other habitats, such as deserts, grasslands, tundra, and temperate forests, all of which are also at risk.

HUMAN CAUSES OF SPECIES ENDANGERMENT

In 2001, the United Nations requested a **Millennium Ecosystem Assessment** to gather scientific information about ecosystem changes and the effects of these changes on human well-being. Several reports were published in 2005 based on the work of more than 1300 scientists from 95 countries. One of these reports, the *Biodiversity Synthesis Report*, examined the important links between ecosystem health and biological diversity. The report stated that biological diversity is declining rapidly due to several factors.

Scientists generally agree that the single greatest threat to biological diversity is land use change, which causes loss of habitat. The spread of invasive species, overexploitation, and pollution (including climate change from CO_2 pollution) are also important. Underlying these direct causes of declining biological diversity are human population increase; increasing economic activity; increased use of technology; and social, political, and cultural factors (**Figure 16.8**). All of these direct and indirect factors interact in complex ways, and so it is most effective to deal with the problem of declining biological diversity using a systems

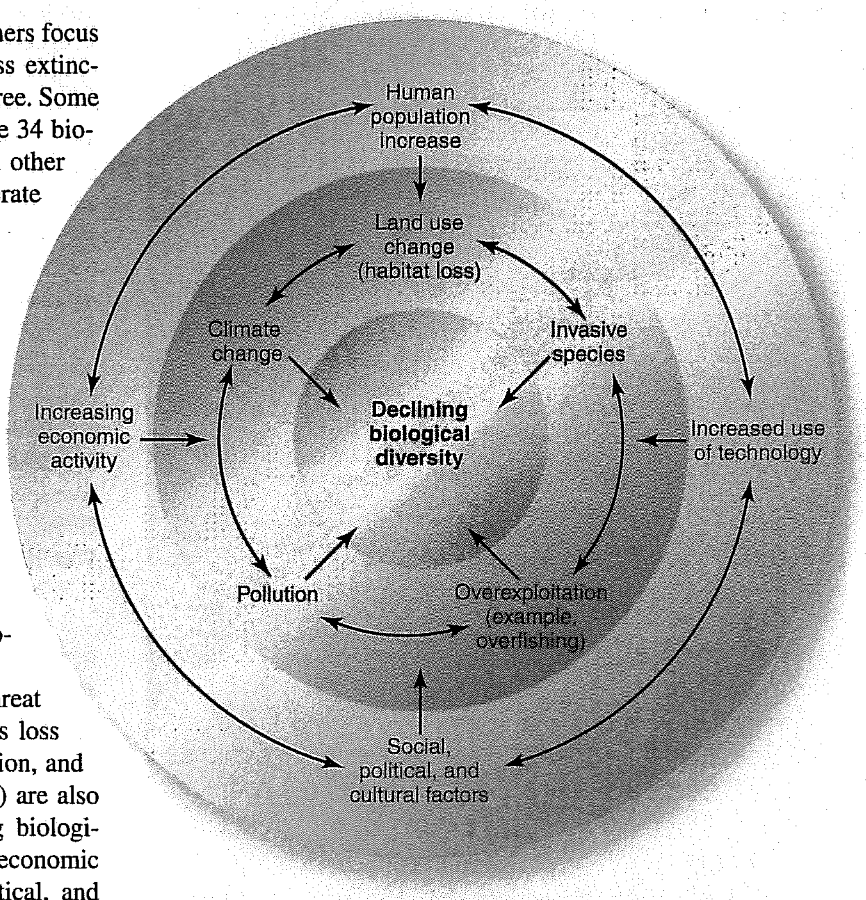


Figure 16.8 Causes of declining biological diversity. In this highly simplified diagram, indirect causes (blue) interact with and amplify the effects of one another and of direct causes (purple).

perspective. Addressing a single factor, such as overexploitation, without considering the other factors that may amplify declining biological diversity is probably doomed to failure.

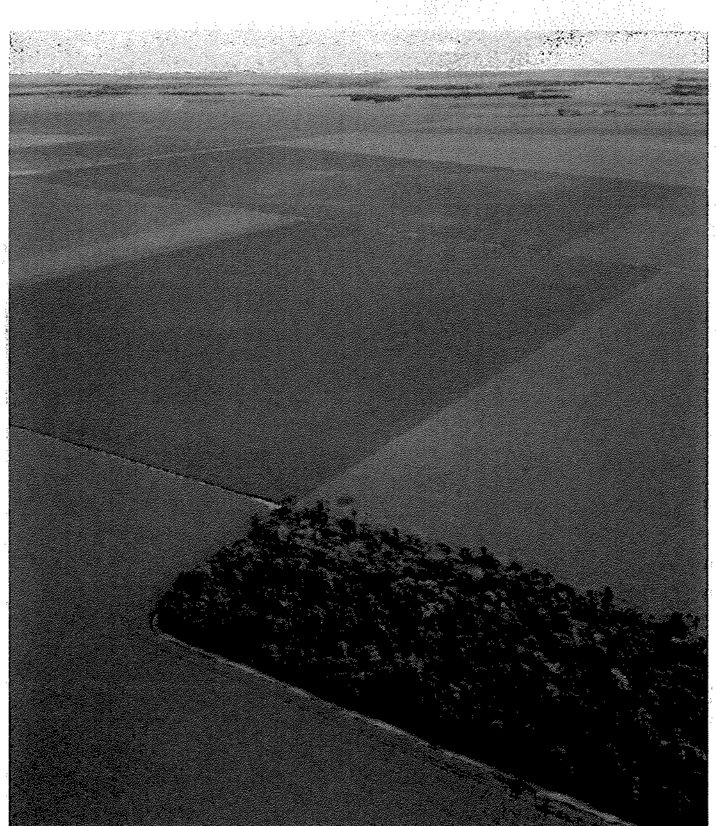
Land Use Change Most species facing extinction today are endangered because of the destruction, fragmentation, or degradation of habitats by human activities. We demolish or alter habitats when we build roads, parking lots, bridges, and buildings; log forests for timber; and clear forests to graze domestic animals or grow crops (**Figure 16.9**; also see Figure 17.11). We drain marshes to build on aquatic habitats, thus converting them to terrestrial ones, and we flood terrestrial habitats when we build dams with their reservoirs. Exploration and mining of minerals, including fossil fuels, disrupt the land and destroy habitats. Habitats are altered by outdoor recreation, including off-road vehicles, hiking off-trail, golfing, skiing, and camping. Because most organisms are utterly dependent on a particular type of environment, habitat destruction reduces their biological range and ability to survive.

As the human population has grown, the need for increased amounts of food has resulted in a huge conversion of forests and other natural lands into croplands and permanent pastures. According to the UN Food and Agriculture Organization, total agricultural lands currently occupy 36% of Earth's land area (see Figure 17.1). Agriculture has a major impact on aquatic ecosystems because of the diversion of water for irrigation.

Little habitat remains for many endangered species. The grizzly bear, for example, occupies about 2% of its original habitat in the lower 48 states of the United States. Human population growth and the extraction of resources have destroyed most of the grizzly's wilderness habitat.

Habitat destruction, fragmentation, and degradation are happening around the world. As entire habitats are transformed for human purposes, many species are becoming extinct, and the genetic diversity within many surviving species is declining.

Africa provides a vivid example of a systems issue—the conflict between humans and species such as elephants over land use. African elephants are nomads that require a lot of natural landscape in which to forage for the hundreds of kilograms of food that each consumes daily. In Africa, people are increasingly pushing into the elephants' territory to grow crops and graze farm animals. A study of 25 African regions with both wild areas and human settlements found that when human density increases to a certain level, the elephants migrate out of the area. The problem is that the wild areas to which elephants can move are steadily shrinking. One of the great challenges is finding a way to allow people and elephants to coexist in an increasingly crowded world.



© John Lee/Aurora Photos

Figure 16.9 Land use change. These soybean fields surround a small sliver of tropical rain forest. Photographed in Mato Grosso, Brazil.

Invasive Species **Biotic pollution**, the introduction of a foreign species into an ecosystem in which it did not evolve, often upsets the balance among the organisms living in that area and interferes with the ecosystem's normal functioning. Unlike other forms of pollution, which may be cleaned up, biotic pollution is usually permanent. The foreign species may compete with native species for food or habitat or may prey on them. Generally, an introduced competitor or predator has a greater negative effect on local organisms than do native competitors or predators. Foreign species whose introduction causes economic or environmental harm are called **invasive species** (**Figure 16.10**).

invasive species Foreign species that spread rapidly in a new area where they are free of predators, parasites, or resource limitations that may have controlled their populations in their native habitat.

Although invasive species may be introduced into new areas by natural means, humans are usually responsible for such introductions, either knowingly or unknowingly. The water hyacinth was deliberately brought from South America to the United States because it has lovely flowers. Today it has become a nuisance in Florida waterways, clogging them to such an extent that boats cannot easily move, and crowding out native species.

Islands are particularly susceptible to the introduction of invasive species. The brown tree snake was accidentally introduced in Guam, an island in the West Pacific, shortly after the end of World War II. Thought to have arrived from the Solomon Islands on a U.S. Navy ship, the brown tree snake thrived and is now estimated to number about 2 million. It consumed rain-forest birds in large numbers; as a result, 9 of Guam's 12 native species of forest birds are extinct in nature. The snakes have also decimated Guam's small reptiles and mammals. In 2013, the U.S. Department of Agriculture began experimental efforts to control the brown snake population by parachute-dropping dead mice laced with acetaminophen, which is toxic to the snake but not to humans.

Overexploitation Sometimes species become endangered or extinct as a result of deliberate efforts to eradicate or control their numbers. Many of these species prey on game animals or livestock. Ranchers, hunters, and government agents have reduced

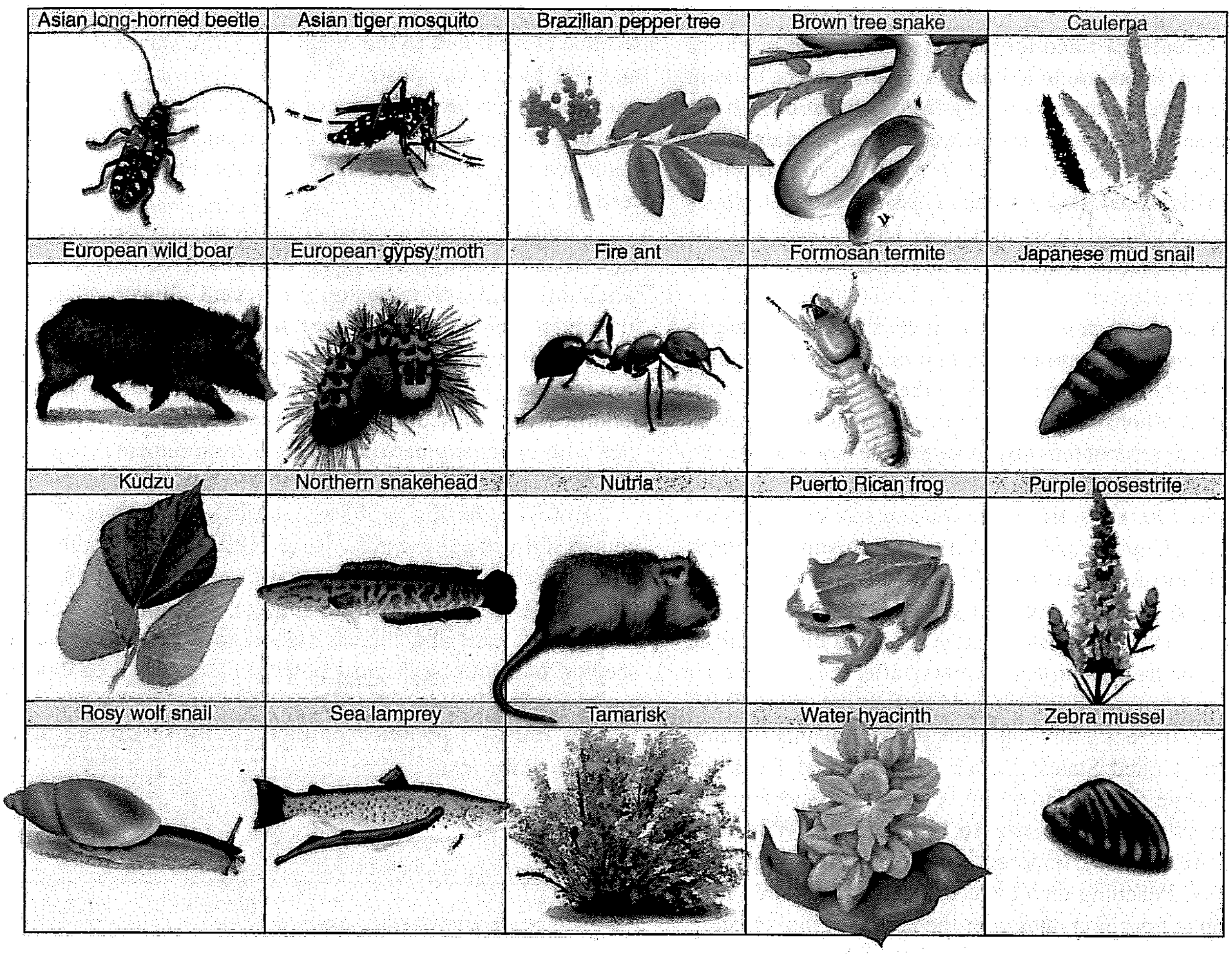


Figure 16.10 Invasive species. Selected examples of the more than 6500 established foreign species that have been accidentally or deliberately introduced into the United States.

populations of large predators such as the wolf and grizzly bear. Predators of game animals and livestock are not the only animals vulnerable to human control efforts. Some animals are killed because their lifestyles cause problems for humans. The Carolina parakeet, a beautiful green, red, and yellow bird endemic to the southern United States, was extinct by 1920, exterminated by farmers because it ate fruit and grain crops.

Unregulated hunting, or overhunting, was a factor contributing to the extinction of certain species in the past but is now strictly controlled in most countries. The passenger pigeon was one of the most common birds in North America in the early 1800s, but a century of overhunting, coupled with habitat loss, resulted in its extinction in the early 1900s. Unregulated hunting was one of several factors that caused the near-extinction of the American bison. Bison were decimated by the U.S. Army, which killed them to disrupt the food supply of the Plains Indians, and by commercial hunters, who killed them for their hides and tongues (considered a choice food) as well as meat for the work crews of railroad companies.

Illegal commercial hunting, or poaching, endangers many larger animals, such as the tiger, cheetah, and snow leopard, whose beautiful furs are quite valuable (**Figure 16.11**). Rhinoceroses are

Figure 16.11 Illegal trade in products made from endangered species. Photographed in Myanmar.

slaughtered primarily for their horns, used for ceremonial dagger handles in the Middle East and for purported medicinal purposes in Asian medicine. Bears are killed for their gallbladders, used in Asian medicine to treat ailments ranging from indigestion to heart disease. Endangered American turtles are captured and exported illegally to China, where they are killed for food. Caimans (reptiles similar to crocodiles) are killed for their skins and made into shoes and handbags. Although all these animals are legally protected, the demand for their products on the black market has caused them to be hunted illegally.

In West Africa, poaching has contributed to the decline in lowland gorilla and chimpanzee populations. The meat (called *bushmeat*) of these rare primates and other protected species, such as anteaters, elephants, and mandrill baboons, provides an important source of protein for indigenous people (see Figure 7.3). Bushmeat is also sold to urban restaurants.

Commercial harvest is the collection and sale of live organisms from nature. Commercially harvested organisms end up in zoos, aquaria, biomedical research laboratories, circuses, and pet stores. Several million birds are commercially harvested each year for the pet trade, but unfortunately, many of them die in transit, and many more die from improper treatment after they are in their owners' homes. Although it is illegal to capture endangered animals from nature, there is a thriving black market, mainly because collectors in the United States, Canada, Europe, and Japan are willing to pay large amounts to obtain a variety of species, particularly rare tropical birds (**Figure 16.12**). The U.S. **Wild Bird Conservation Act** of 1992 imposed a moratorium on importing rare bird species. Poaching data collected before and after 1992 indicated a drop in poaching rates after the law went into effect.

Animals are not the only organisms threatened by excessive commercial harvest. Many unique and rare plants have been collected from nature to the point that they are endangered. These include carnivorous plants, wildflower bulbs, certain cacti, and orchids.

Pollution Human-produced acid rain, stratospheric ozone depletion, and climate change degrade even wilderness habitats that are otherwise natural and undisturbed. Acid rain is thought to have contributed to the decline of large stands of forest trees and the biological death of many freshwater lakes. Because ozone in the upper atmosphere shields the ground from a large proportion of the sun's harmful ultraviolet (UV) radiation, ozone depletion in the upper atmosphere represents a threat to all terrestrial life.

Climate warming, caused in part by an increase in atmospheric CO_2 released when fossil fuels are burned, is another threat. Overwhelming evidence indicates that recent climate changes have already affected biological diversity. Further climate change is expected to increase the rate of extinction, particularly in certain regions such as polar areas and alpine habitats. Such habitat modifications particularly reduce the biological diversity of species with extremely narrow and rigid environmental requirements (discussed further in Chapter 20).

Excessive fertilizer use has contributed to high levels of nutrients in soil and aquatic ecosystems. Other types of pollutants that affect organisms include industrial chemicals, agricultural pesticides, organic pollutants from sewage, antibiotics and hormones from agriculture and human prescriptions, acid mine drainage seeping from mines, thermal pollution from the heated wastewater of industrial plants, and plastics (**Figure 16.13**). The effects of various forms of pollution on biological diversity are discussed throughout the text.

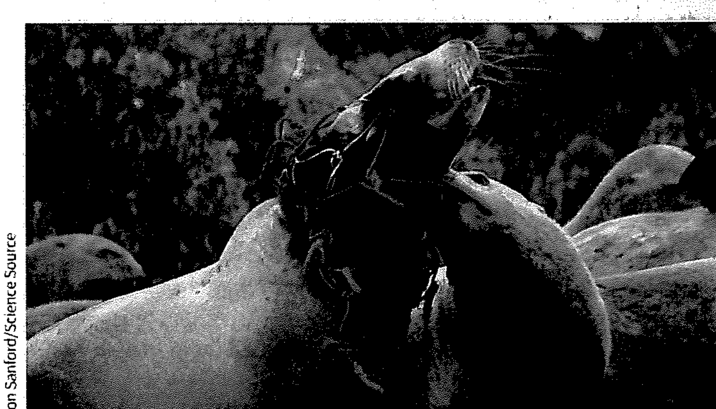
CASE IN POINT

DISAPPEARING FROGS

Of all this chapter's examples of species in trouble, frogs and other amphibians deserve special notice. Many scientists think amphibians are **indicator species** that provide an early warning of environmental damage with the potential to affect other species. Amphibians also merit attention because precipitous declines in amphibian populations are occurring around the world. These

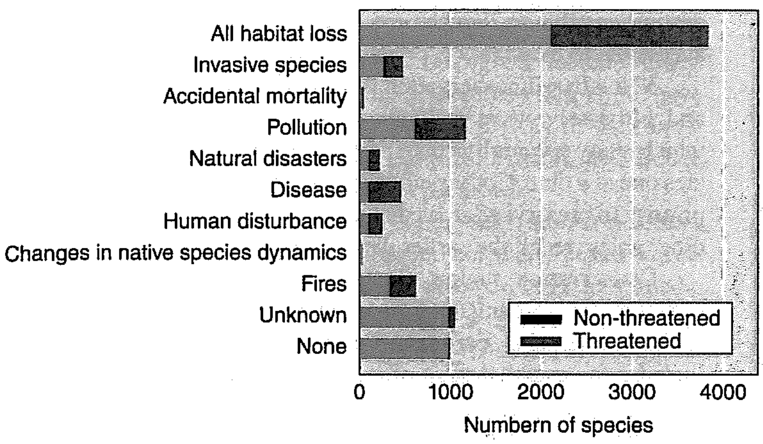
© NHPA/Photoshot

Figure 16.12 Illegal animal trade. These parrots, captured illegally in the South American jungle, were confiscated at an animal black market in Peru.



Ron Sanford/Science Source

Figure 16.13 Plastic pollution harms wildlife. The plastic from a broken fishing net has ensnared a stellar sea lion (*Eumetopias jubatus*), and part of the net is cutting into the seal's neck. Photographed in Alaska.



(a) The IUCN has identified a range of threats to global amphibian species.

Suzanne L. & Joseph T. Collins/Science Source

(b) Pollution and parasites are implicated in frog deformities, developmental abnormalities such as the extra leg on this plains leopard frog (*Rana blairi*). Photographed in Leavenworth County, Kansas.

Figure 16.14 Frogs in trouble.

animals face many documented threats, some of which are particularly acute to threatened species (**Figure 16.14a**).

Amphibians, represented by about 7000 species of frogs, toads, and salamanders, have existed as a group for more than 350 million years. Despite their evolutionary resilience, amphibians are remarkably sensitive environmental indicators in both aquatic and terrestrial ecosystems. Amphibians typically spend part of their life in water and part on land. Most frogs lay gelatinous and unprotected eggs in ponds and other pools of standing water, and tadpoles (immature frogs) undergo metamorphosis in water, maturing into adult frogs that live on land. As adults, frogs breathe primarily through their permeable skin. This moist, absorptive skin makes frogs susceptible to environmental contaminants.

Since the 1970s, many of the world's frog populations have dwindled or disappeared. At least 42% of known amphibian species are declining, and approximately 165 species are believed to be extinct. Habitat loss is the greatest threat to amphibians, but researchers have observed that the declines are not limited to areas with obvious habitat destruction. Some remote, pristine locations also show dramatic declines in amphibians. Biologists are not certain what is causing these declines, and it appears no single factor is responsible. Factors with scientific support include pollutants, infectious diseases, and climate change.

Agricultural chemicals are implicated in amphibian declines in California's Sierra Nevada. Frog populations on the eastern slopes are relatively healthy, but about eight species are declining on the western slopes, where prevailing winds carry residues of pesticides from the Central Valley, a huge agricultural region. Agricultural chemicals may also be contributing to amphibian declines in Maryland and in Ontario, Canada.

A *chytrid* (fungus) is responsible for massive die-offs of more than 100 amphibian species around the world. Climate change may be exacerbating chytrid-induced amphibian deaths. At certain altitudes and temperatures, the chytrid has infected and killed 85% of the amphibians.

Amphibian Deformities The discovery in some areas of frogs and other amphibians with deformities adds another layer of complexity to the amphibian crisis. Deformed frogs—with extra legs, extra toes, eyes located on the shoulder or back, deformed jaws, bent spines, missing legs, missing toes, and missing eyes—usually die before they reproduce (**Figure 16.14b**). Predators easily catch frogs with extra or missing legs. Since the discovery of deformed frogs in Minnesota in 1995, amphibian deformities have been found in most U.S. states and on four continents.

Several factors may produce amphibian deformities. Some pesticides affect normal development in frog embryos. Also, infecting tadpoles with a *trematode* (a parasitic flatworm) causes the developing adults to exhibit limb deformities. Multiple environmental stressors, such as habitat loss, disease, and air and water pollution, may interact synergistically with one another to cause deformities. For example, an amphibian stressed by pesticide residues or drought may be more susceptible to a parasite. In 2008, scientists confirmed a positive link between the level of atrazine (a herbicide) in water samples and the number of trematodes infecting northern leopard frogs living in the water. ■

REVIEW

1. How do you distinguish between background extinction and mass extinction events?
2. What are endangered species? Threatened species?
3. What are biodiversity hotspots? Where are most biodiversity hotspots located?
4. What is the most significant cause of species endangerment and extinction?
5. How can an invasive species endanger native species?

Conservation Biology

LEARNING OBJECTIVES

- Define *conservation biology* and compare in situ and ex situ conservation.
- Describe restoration ecology.

conservation biology The scientific study of how humans impact organisms and of the development of ways to protect biological diversity.

What strategies should we develop to cope with declining biological diversity? The broad field of **conservation biology** addresses these concerns. Conservation biology ranges from studying the processes that influence a decline in biological diversity, to protecting and restoring populations of endangered species, to preserving entire ecosystems and landscapes. Conservation biologists develop models, design experiments, and perform fieldwork to address this range of questions.

Conservation biologists have demonstrated that a single large area of habitat, which has the potential to support large populations, is generally more effective at safeguarding an endangered species than several habitat fragments, each with the potential to support small populations. A large area of habitat also has the potential to support greater species richness than several habitat fragments.

It is better if areas of habitat for a given species are located close together rather than far apart. If an area of habitat is isolated from other areas, individuals of a species may not effectively disperse from one habitat to another. Because the presence of humans adversely affects many species, areas that lack roads or are inaccessible to humans are better habitats than areas that are accessible to humans.

Virtually all conservation biologists think it is more effective and, ultimately, more economical to preserve intact ecosystems in which many species live than to work on preserving individual species one at a time. Conservation biologists typically assign a higher priority to preserving areas that are more biologically diverse than other areas (recall the earlier discussion of biodiversity hotspots).

Conservation biology includes two problem-solving techniques to save organisms from extinction: in situ and ex situ conservation. **In situ conservation** (on-site conservation), which includes the establishment of parks and reserves, concentrates on preserving biological diversity in nature. A high priority of in situ conservation is identifying and protecting sites that harbor a great deal of diversity. With increasing demands on land, in situ conservation cannot guarantee the preservation of all types of biological diversity. Sometimes only ex situ conservation can save a species.

Ex situ conservation (off-site conservation) involves conserving biological diversity in human-controlled settings. The breeding of captive species in zoos (such as the condors discussed earlier in the chapter) and the seed storage of genetically diverse plant crops are examples of ex situ conservation.

IN SITU CONSERVATION: PROTECTING HABITATS

Protecting animal and plant habitats—that is, conserving and managing the ecosystem as a whole—is the single best way to preserve biological diversity. Because human activities have adversely affected the sustainability of many of Earth's ecosystems, direct conservation management of protected areas is often required (**Figure 16.15**).

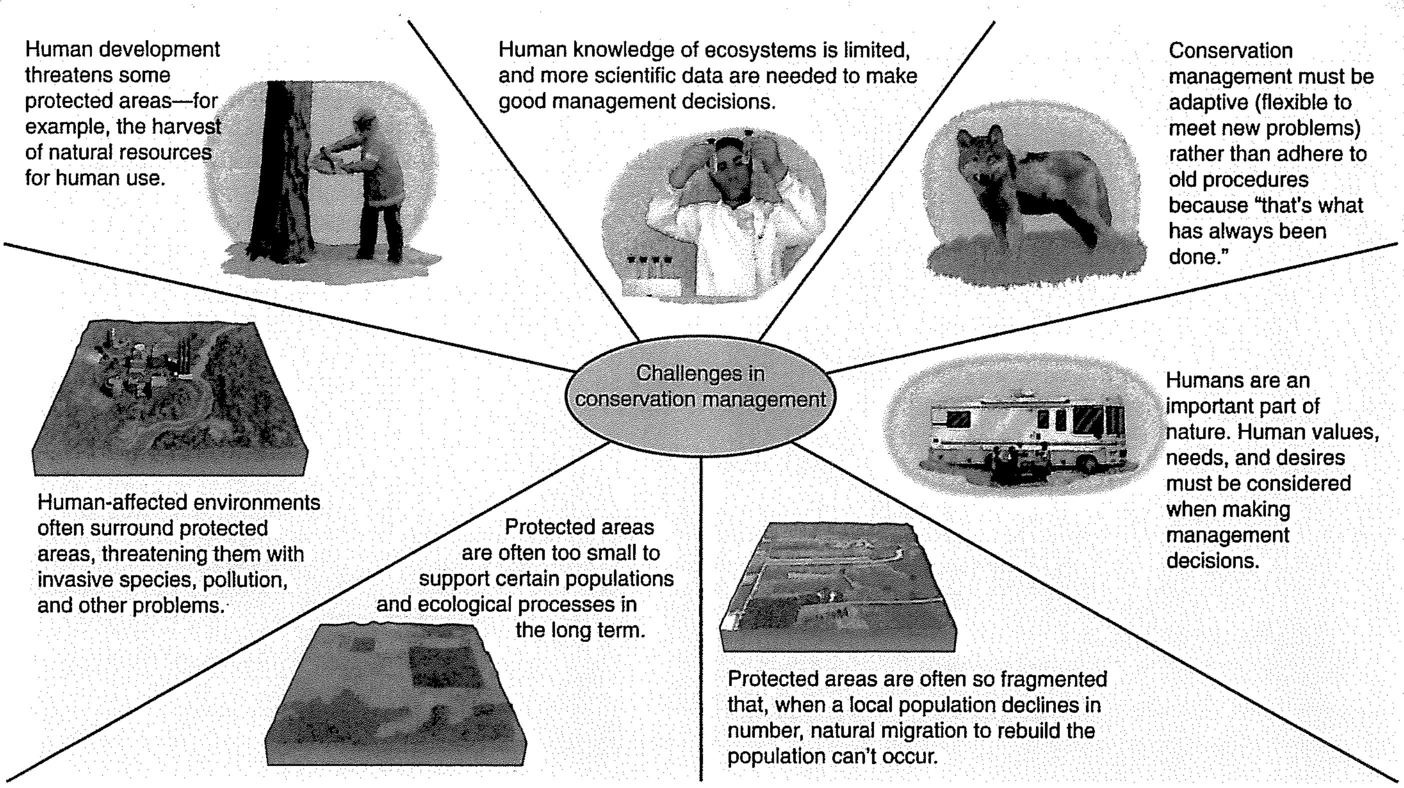


Figure 16.15 Some challenges in conservation management.

Many nations appreciate the need to protect their biological heritage and have set aside areas for biological habitats. Ecuador, Venezuela, Denmark, and the Dominican Republic have established protected areas totaling more than 30% of their land. Austria, Germany, New Zealand, Slovakia, Bhutan, and Belize have more than 20% of their land areas protected.

Currently, more than 100,000 national parks, marine sanctuaries, wildlife refuges, forests, and other protected areas exist worldwide. These encompass a total area almost as large as Canada. Some of these areas were set aside to protect specific endangered species. The world's first such refuge was established in 1903 at Pelican Island, Florida, to protect the brown pelican. Today the U.S. National Wildlife Refuge System has land set aside in more than 560 refuges. Although the bulk of the protected land is in Alaska, refuges exist in all 50 states.

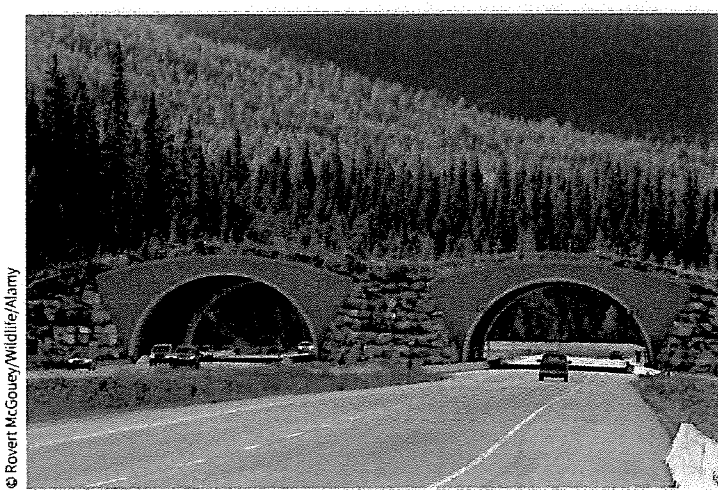
Many protected areas have multiple uses that sometimes conflict with the goal of preserving species. National parks provide for recreation, and national forests may be open for logging, grazing, and mineral extraction. The mineral rights in many wildlife refuges are privately owned, and some wildlife refuges have played host to military exercises.

Protected areas are not always effective in preserving biological diversity, particularly in poorer countries, often where biological diversity is greatest, because there is little money or expertise to manage them. Such sites, where governments are unable or unwilling to enforce conservation laws, are vulnerable to logging, farming, mining, and poaching.

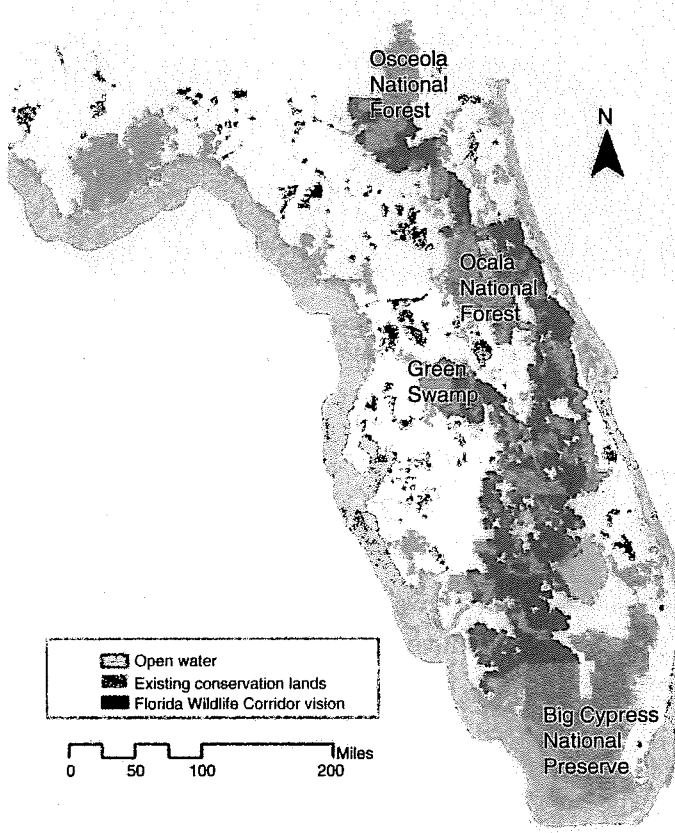
Another shortcoming of the world's protected areas is that many are in lightly populated mountain areas, tundra, and the driest deserts, places that often have spectacular scenery but relatively few kinds of species. Such remote areas are often designated reserves because they are unsuitable for commercial development. In contrast, ecosystems in which biological diversity is greatest often receive little protection. Protected areas are urgently needed in tropical rain forests, the tropical grasslands and savannas of Brazil and Australia, and dry forests widely scattered around the world. Desert organisms are underprotected in northern Africa and Argentina, and many islands and temperate river basins need protection.

Worldwide, about 11.5% of Earth's land area—nearly 19 million km^2 (7.3 million mi^2)—has been set aside to protect biological diversity. However, many existing protected areas are too small or too isolated from other protected areas to effectively conserve species. Also, the habitats for more than 700 highly endangered mammals, birds, reptiles, and amphibians are not included in the global network of protected areas.

Connecting Fragmented Habitats Conservation biologists have proposed setting aside **habitat corridors**, which are strips of habitat that connect isolated habitat fragments. Habitat corridors, also called *wildlife corridors*, allow wild organisms to move from one fragment to another so they can feed, mate, and recolonize habitats should local extinctions occur. Some habitat corridors are very small, such as an underpass or overpass that allows wildlife to cross a road safely (**Figure 16.16a**). Other habitat corridors are large (e.g., several kilometers of forest) and connect separate wildlife reserves (see Meeting the Challenge: Dealing Effectively with Fragmented Habitats; also see **Figure 16.16b** for an example of proposed habitat corridors).



(a) Close-up of wildlife overpass. Without habitat corridors under or over highways, grizzly bears and other wildlife must cross dangerous roads or avoid moving to new areas. Photographed in Banff National Park, Alberta, Canada.



(b) Proposed habitat corridors to link Florida wilderness areas, as designed by the ongoing Florida Wildlife Corridor project.

Figure 16.16 Habitat corridors.

RESTORING DAMAGED OR DESTROYED HABITATS

Although preserving habitats is an important part of conservation biology, the realities of our world, including the fact that the land-hungry human population continues to increase, dictate a variety of other conservation measures. Scientists can reclaim disturbed lands and convert them into areas with high biological diversity.

Restoration ecology, in which the principles of ecology are used to help return a degraded environment to a more functional and sustainable one, is an important part of in situ conservation. (**Figure 16.17**)

restoration ecology The study of the historical condition of a human-damaged ecosystem, with the goal of returning it as close as possible to its former state.

Since 1934, the University of Wisconsin–Madison Arboretum has carried out one of the world's most famous examples of restoration ecology. During that time, several distinct natural communities of Wisconsin were carefully developed on damaged agricultural land. These communities include a tallgrass prairie, a dry prairie, and several types of pine and maple forests. Today hundreds of species of native plants, birds, mammals, and insects live in the restoration site.

Restoration of disturbed lands creates biological habitats and has additional benefits such as the regeneration of soil damaged by agriculture or mining. The disadvantages of restoration include the expense and the amount of time it requires to restore an area. Even so, restoration is an important aspect of conservation biology, because it is thought that restoration will reduce extinctions.

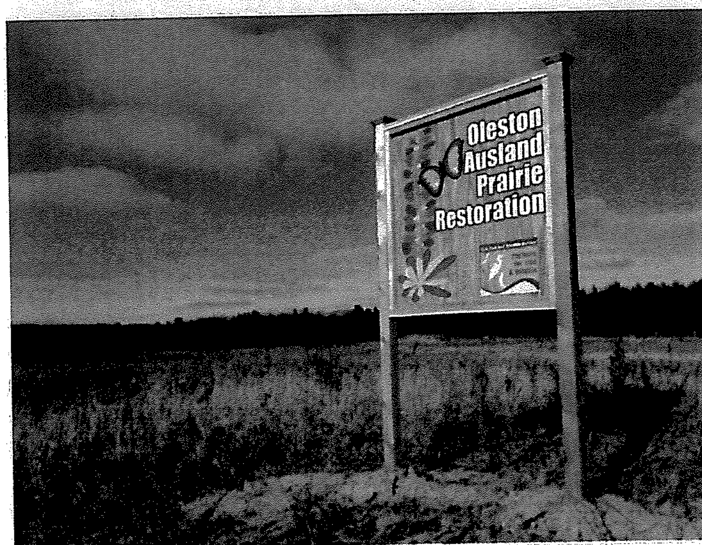


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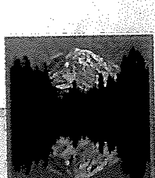
Figure 16.17 **Prairie restoration.** Principles of restoration ecology were applied to restoring a midwestern farm, overgrown with trees, to prairie habitat.

ZOOS, AQUARIA, BOTANICAL GARDENS, AND SEED BANKS

Zoos, aquaria, and botanical gardens often play a critical role in saving individual species on the brink of extinction. Eggs may be collected from nature, or the remaining few wild animals may be captured and bred in zoos, aquaria, and other research environments.

Special techniques, such as artificial insemination and embryo transfer, are used to increase the number of wild animal offspring. In **artificial insemination**, sperm collected from a suitable male of a rare species is used to artificially impregnate a female, perhaps located in another zoo in a different city or even in another country. In **embryo transfer**, a female of a rare species is treated with fertility drugs, which cause her to produce multiple eggs. Some of these eggs are collected, fertilized with sperm, and surgically implanted into a female of a related but less rare species, who later gives birth to offspring of the rare species. Another technique involves hormone patches to stimulate reproduction in endangered birds; the patch is attached under the female bird's wing.



MEETING THE CHALLENGE

Dealing Effectively with Fragmented Habitats

Collaboration among diverse sets of stakeholders is crucial to meeting the challenge of designing and implementing a system of habitat corridors among fragmented habitats. Two recent examples of corridor planning that illustrate the principles of successful collaboration are located on two different continents. The *Mesoamerican Biological Corridor* connects fragments of tropical forests from Mexico through Panama, and the *Bossou-Nimba Green Corridor Project* is located in Africa in the country of Guinea.

These corridor projects involve a diverse array of intergovernmental partnerships that incorporate conservation biology, citizen science, and ecological economics. Both corridor projects evolved around the habitat needs of large mammal species. For the Mesoamerican Corridor, the focus was on creating a habitat network large enough to facilitate jaguar movement, and for the Green Corridor, the emphasis was on maintaining gene flow among isolated chimpanzee populations. Thus, both corridor projects are tied to a **flagship species**, which is an organism that captures the public's imagination.

Because connecting fragments of tropical forest habitat requires planting trees, both projects also involved *ecological restoration*. Public acceptance of corridor construction was enhanced in several ways. In Costa Rica, the Mesoamerican Corridor is widely used to promote ecotourism, but individual landowners are also compensated for replanting trees through tax credits that are linked to a reduction in global carbon dioxide levels and to improved water quality. In Guinea, forest restoration stimulates local economies because the planted trees produce fruits (oranges, mangoes, and mandarin oranges) and nuts.

The challenge of monitoring how jaguars, chimpanzees, and other wildlife species use these corridors is being met through commitments to environmental education. Each corridor project has developed a system of promoting **citizen science**, whereby people living adjacent to the corridor are trained and become responsible for annual biodiversity surveys within the protected corridor. Citizen scientists also report the occurrence of destructive uses of corridor land. Thus, neighbors—rather than police, military, or international entities—enforce laws against poaching and timber harvesting.

ENVIRONEWS ON CAMPUS

Restoring the Drew University Forest Preserve

Environmental science students at New Jersey's Drew University learn for themselves how to restore ecosystems. The campus's forest ecosystem had become degraded by invasive plant species, an unchecked deer population, and habitat fragmentation. A carefully planned and implemented restoration program activated teams of students and other volunteers to build a special deer exclosure fence, remove invasive plants, and replant with native plant species.

The collaborative effort included partnerships with the U.S. Fish and Wildlife Service, the New Jersey Audubon Society, private industries, and local naturalists. Biodiversity in the preserve has increased substantially as the native plants have established. The site serves as a prime educational tool for both the university and the community, and is the focus of much ecological research.

Drew University students extend their restoration efforts beyond the forest preserve. An annual "Fern Fest" event during Earth Week replaces a portion of the campus lawn with native ferns and wildflowers, with the goal of increasing biodiversity and further restoring the former forest ecosystem. A rain garden and native meadow have also been constructed, and a campus-wide policy directs the use of native species for all other plantings.

Scientists have learned to successfully breed endangered whooping cranes in captivity. The captive population now totals 157 cranes. Four wild whooping crane populations currently exist—in Florida (nonmigratory), Louisiana (nonmigratory), Texas-Canada (migratory), and Wisconsin-Florida (migratory). In late 2013, the total number of wild cranes was 454. Scientists are trying to enhance existing flocks and establish additional flocks in the wild by soft-releasing cranes (for a nonmigratory flock) or flying them behind an ultralight aircraft (for a migratory flock). (In *soft release*, the birds are initially placed in a specially constructed pen to help them adjust before being released into the wild.) The Louisiana population was established by soft release in 2011 and produced eggs in 2014, the first in the state in 75 years.

Attempting to save a species on the brink of extinction is expensive, and only a small proportion of endangered species can be saved. Because zoos, aquaria, and botanical gardens do not have the space or money to save all endangered species, conservation biologists must prioritize which species they will attempt to save. Clearly, it is more cost-effective to maintain existing natural habitats so that species will never become endangered in the first place.

Reintroducing Endangered Species to Nature The ultimate goal of captive-breeding programs is to produce offspring in captivity and then release them into nature so that wild populations can be restored. However, only 1 of every 10 reintroductions using animals raised in captivity is successful. What guarantees that a reintroduced population will survive?

Whether such reintroductions actually succeed has been evaluated only in recent years. The Hawaiian goose, or nene (pronounced *nay-nay*), was down to 30 individuals in the 1960s. It was reintroduced to the islands of Hawaii (the Big Island) and Maui beginning in the 1970s, but although hundreds of birds have been released, self-sustaining nene populations have been slow to develop. Apparently, some of the same factors that originally caused the nene's extinction in nature, including habitat destruction and foreign predators such as the Indian mongoose, are responsible for the failure of the reintroduced birds. On Kauai, a group of captive nenes escaped during a hurricane and are successfully reestablishing themselves, with a 2011 estimated population of 1400–1600 birds. Kauai is less developed than Maui or the Big Island and does not have the Indian mongoose. The statewide nene population was estimated at 2500 in 2011, including a fairly stable population on Maui, but it remains dependent on the regular release of captive-bred birds.

Before attempting a reintroduction, conservation biologists now undertake a feasibility study. This study includes determining what factors originally caused the species to become extinct in nature, whether these factors still exist, and whether any suitable habitat still remains.

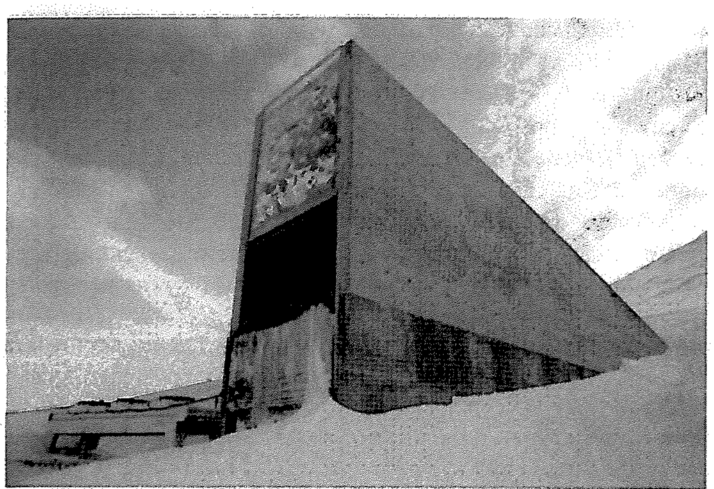
If the animal to be reintroduced is a social animal, a small herd is usually released together. This is accomplished by first placing the herd in a large, semiwild enclosure that is somewhat protected from predators but that requires the herd to obtain its own food. When the herd's behavior begins to resemble the behavior of wild herds, it is released.

Sometimes it is impossible to teach critical survival skills to animals raised in captivity. The effort to reintroduce captive-raised thick-billed parrots to the Chiricahua Mountains of Arizona was canceled in 1993 because all 88 birds released between 1986 and 1993 died or disappeared. Wild, thick-billed parrots are loud, sociable birds whose flocking instinct contributes to their survival because individual birds loudly announce the presence of danger, such as hawks or other birds of prey, to the group. Those parrots raised in captivity lacked such social behavior, and despite efforts to teach them to stay together, they separated from the flock after they were released.

Once animals are released, they must be monitored. If any animals die, their cause of death is determined so scientists can search for ways to prevent unnecessary deaths in future reintroductions.

Seed Banks More than 100 seed collections called **seed banks**, or *gene banks*, exist around the world and collectively hold more than 3 million samples at low temperatures. The Svalbard Global Seed Vault, sometimes called the Doomsday Vault, stores known varieties of 150 widely grown crop plants (**Figure 16.18**). The Millennium Seed Bank Partnership of the Royal Botanic Garden in Kew stores seeds from 10% of the world's known wild plant species. Seed banks offer the advantage of storing a large amount of plant genetic material in a small space. Seeds stored in seed banks are safe from habitat destruction, climate change, and general neglect. There have even been some instances of using seeds from seed banks to reintroduce to nature a plant species that had become extinct.

Seeds do not remain alive indefinitely and must be germinated periodically so that new seeds can be collected. Growing, harvesting, and returning seeds to storage are the most expensive steps in storing plant material in seed banks. (Cryopreservation



Paul Nicklen/National Geographic Creative

Figure 16.18 Svalbard Global Seed Vault. Located in Svalbard, Norway, this seed bank stores seeds of some 1.5 million varieties of the 150 most important species of crop plants. How might climate change impact the success of using seeds from this seed bank to replace a locally extinct variety?

in liquid nitrogen at −160°C, or −256°F, is being developed for certain kinds of seeds. Seeds stored at this temperature survive for longer periods than seeds stored at warmer temperatures.) Because accidents such as fires or power failures can result in the permanent loss of the genetic diversity in the seeds, biologists typically subdivide seed samples and store them in several seed banks.

Perhaps the most important disadvantage of seed banks is that plants stored in this manner remain stagnant in an evolutionary sense. They do not evolve in response to changes in their natural environments, such as climate warming. As a result, they may be less fit for survival when they are reintroduced into nature. Despite their shortcomings, seed banks are increasingly viewed as an important method of safeguarding seeds for future generations.

Many individuals, small businesses, and organizations (e.g., the Sustainable Mountain Agriculture Center in Berea, Kentucky), act on their own to preserve seeds and cultivate traditional vegetable varieties no longer grown widely on farms. Often referred to as *heirloom vegetables*, these open-pollinated species typically have more flavor than their hybrid counterparts.

CONSERVATION ORGANIZATIONS

Conservation organizations are an essential part of the effort to maintain biological diversity. These groups help educate policymakers and the public about the importance of biological diversity. In certain instances, they serve as catalysts and galvanize public support for important biodiversity preservation efforts. They provide financial support for conservation projects, from basic research to the purchase of land that is a critical habitat for a particular species or group of species.

The IUCN assists countries with hundreds of conservation biology projects. The IUCN and other conservation organizations are currently assessing how effective established wildlife refuges are in maintaining biological diversity. For example, researchers are investigating the minimum size that a protected area requires to avoid species encroaching from surrounding areas. The WWF and Brazil's National Institute for Amazon Research Biological Dynamics are conducting a long-term study on the effects of habitat fragmentation on the Amazonian rain forest by using 1-hectare, 10-hectare, and 100-hectare forest fragments, along with controls of identically sized sections in intact forest. Preliminary data indicate that the smaller forest fragments do not maintain their ecological integrity. For example, many bird species that live in the central Amazon are not found in the smaller habitat fragments.

In addition, the IUCN and the WWF have identified major conservation priorities by determining which biomes and ecosystems do not have protected areas. The IUCN maintains a data bank on the status of the world's species; its material is published in the *IUCN Red Data Books* about organisms and their habitats.

REVIEW

1. What is conservation biology?
2. Is restoration ecology an important aspect of in situ or ex situ conservation?

Conservation Policies and Laws

LEARNING OBJECTIVE

- Briefly describe the U.S. Endangered Species Act.

In 1973 the **Endangered Species Act (ESA)** was passed in the United States, authorizing the U.S. Fish and Wildlife Service (FWS) to protect endangered and threatened species in the United States and abroad. Many other countries now have similar legislation. The ESA requires a detailed study of a species to determine if it should be listed as endangered or threatened. Currently, more than 1500 species in the United States are listed as endangered or threatened. The ESA provides legal protection to listed species to help reduce their danger of extinction. This act makes it illegal to sell or buy any product made from an endangered or threatened species.

The ESA requires the FWS to select critical habitats and design a detailed recovery plan for each species listed. The recovery plan includes an estimate of the current population size, an analysis of what factors contributed to its endangerment, and a list of activities to help the population recover. Currently, 1145 U.S. endangered or threatened species have approved recovery plans.

The ESA was updated in 1982, 1985, and 1988. It is considered one of the strongest pieces of U.S. environmental legislation, in part because species are designated as endangered or threatened entirely on biological grounds. Currently, economic considerations cannot influence the designation of endangered or threatened species. Biologists generally agree that as a result of passage of the ESA in 1973, fewer species became extinct than would have if the law had not been passed.

The ESA is one of the most controversial pieces of environmental legislation. It does not provide compensation for private property owners who suffer financial losses because they cannot develop their land if a threatened or endangered species lives there. The ESA has also interfered with some federally funded development projects.

The ESA was scheduled for congressional reauthorization in 1992 but has been entangled since then in political wrangling between conservation advocates and those who support private property rights. Conservation advocates think the ESA does not do enough to save endangered species, whereas those who own land on which rare species live think the law goes too far and infringes on property rights. Another contentious issue is the financial cost of the law. Critics say that federal and state governments spend too much, given the little bit of environmental gain that the ESA accomplishes. Some critics—notably business interests and private property owners—view the ESA as an impediment to economic progress.

Those who defend the ESA point out that of 34,000 past cases of endangered species versus economic development, only 21 cases were not resolved by some sort of compromise. Compromise is crucial to the success of saving endangered species because, according to the U.S. General Accounting Office, more than 90% of endangered species live on at least some privately owned lands. Some critics of the ESA think the law should be changed so that private landowners are given economic incentives to help save endangered species living on their lands. For example, tax cuts for property owners who are good land stewards could make the presence of endangered species on their properties an asset instead of a liability.

Defenders of the ESA agree that the law is not perfect. Relatively few endangered species have recovered enough to be delisted—that is, removed from protection of the ESA. However, the FWS reports that hundreds of listed species are stable or improving; it expects as many as several dozen additional species to be delisted in the next decade or so (**Figure 16.19**). However, many species are considered *conservation reliant*—that is, they may never recover sufficiently to be delisted.

Figure 16.19 Delisting of the brown pelican. The brown pelican population, endangered due to hunting, habitat destruction, and the pesticide DDT, had recovered sufficiently by 2009 to remove it from the threatened and endangered species list.

The ESA is geared more to saving a few popular or unique endangered species rather than the much larger number of less glamorous species, such as fungi and insects, that perform valuable ecosystem services. Yet it is the less glamorous organisms that play central roles in ecosystems and contribute the most to their functioning.

Conservationists would like the ESA to be strengthened in such a way as to manage whole ecosystems and maintain complete biological diversity rather than attempt to save endangered species as isolated entities. This approach would offer collective protection to many declining species rather than to single species.

HABITAT CONSERVATION PLANS

The 1982 amendment of the ESA provided a way to resolve conflicts between protection of endangered species and development interests on private property: **habitat conservation plans (HCPs)**. HCPs vary greatly, from small projects to regional conservation and development plans.

Habitat conservation plans allow a landowner to "take" (injure, kill, or modify the habitat of) a rare species if the "taking" doesn't threaten the survival or recovery of the threatened or endangered species on that property. If a landowner sets aside land as habitat for the rare species, he or she then has the right to develop part of the property without threat of legal action by the FWS. Conservationists point out that HCPs do not provide any promise of recovery of rare species. In some cases, conservationists are concerned that HCPs may actually contribute to a species' extinction.

INTERNATIONAL CONSERVATION POLICIES AND LAWS

The **World Conservation Strategy**, a plan designed to conserve biological diversity worldwide, was formulated in 1980 by the IUCN, the WWF, and the UN Environment Programme. In addition to providing guidelines for conserving biological diversity, the World Conservation Strategy seeks to preserve the vital ecosystem services on which all life depends for survival and to develop sustainable uses of organisms and the ecosystems that they compose.

The **Convention on Biological Diversity** was produced by the 1992 Earth Summit to decrease the rate of extinction of the world's endangered species. This treaty requires that each signatory nation inventory its own biodiversity and develop a **national conservation strategy**, a detailed plan for managing and preserving the biological diversity of that specific country. Despite an increase in conservation efforts since the Earth Summit, however, the loss of biological diversity is not declining.

The exploitation of endangered species is somewhat controlled at the international level by the **Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES)**, which went into effect in 1975. Originally drawn up to protect endangered animals and plants considered valuable in the highly lucrative international wildlife trade, CITES bans the hunting, capturing, and selling of endangered or threatened species and regulates the trade of organisms listed as potentially threatened. Unfortunately, enforcement of this treaty varies from country to country. Even where enforcement exists, the penalties aren't severe. As a result, illegal trade in rare, commercially valuable species continues.

The African elephant, discussed earlier in the chapter, bears out these problems. Listed as an endangered species since 1989 to halt the slaughter of elephants driven by the ivory trade, the species seemed to have recovered in southern Africa. However, poaching rebounded in the 2000s, and an estimated 65% of forest elephants were killed between 2002 and 2013. According to wildlife specialists, by 2013 about 9% of the African elephant population was being killed for ivory each year. This level of slaughter is greater than the level in 1989, when the ban went into effect. Much of the illegally obtained ivory is sold online.

The goals of CITES often stir up controversy over such issues as who actually owns the world's wildlife and whether global conservation concerns take precedence over competing local interests. These conflicts often highlight socioeconomic differences between wealthy consumers of CITES products and poor people who trade in endangered organisms.

REVIEW

1. What is the Endangered Species Act and what has it accomplished?

Wildlife Management

LEARNING OBJECTIVE

- Distinguish between conservation biology and wildlife management.

Wildlife management is an applied field of conservation biology that focuses on the continued productivity of plants and animals. Wildlife management programs often have different priorities than those of conservation biology. In contrast to conservation biology, which often focuses on threatened or endangered species, most attention in wildlife management is focused on common organisms. Wildlife management includes the regulation of hunting and fishing and the management of food, water, and habitat.

wildlife management The application of conservation principles to manage wild species and their habitats for human benefit or for the welfare of other species.

The natural predators of many game animals have been largely eliminated in the United States. As a result of the near-disappearance of predators such as wolves, the populations of animals such as squirrels, ducks, and deer sometimes exceed the carrying capacity of their environment (see Chapter 5). When this occurs, the habitat deteriorates, and many animals starve to death. Sport hunting effectively controls the overpopulation of game animals, provided restrictions are observed to prevent overhunting. Laws in the United States determine the time of year and length of hunting seasons for various species, as well as the number, sex, and physical size of each species that may be harvested.

Wildlife managers manipulate the plant cover, food, and water supplies of a specific animal's habitat. Because different animals predominate in different stages of ecological succession, controlling the stage of ecological succession of an area's vegetation encourages the presence of certain animals and discourages the presence of others (see Chapter 5). Quail and ring-necked pheasant are found in grassy, open areas characteristic of early-succession stages. Moose, deer, and elk predominate in partially open forest, such as a meadow adjacent to a forest; the meadow provides food, and the forest provides protective cover. Other animals, such as grizzly bears and bighorn sheep, require undisturbed vegetation. Wildlife managers control the stage of succession with techniques such as planting certain types of vegetation, burning the undergrowth with controlled fires, and building artificial ponds.

MANAGEMENT OF MIGRATORY ANIMALS

International agreements are established to protect migratory animals. Ducks, geese, and shorebirds spend their summers in Canada and their winters in the United States and Central America. During the course of their annual migrations, which usually follow established routes, or **flyways**, they must have areas in which to rest and feed. Wetlands, the habitat of these animals, must be protected in both their winter and summer homes.

Arctic Snow Geese The Arctic snow goose has become a major challenge for wildlife managers because its population expanded rapidly beginning in the 1980s. This goose breeds in large colonies along coastal salt marshes of the Arctic during the short Arctic summer. The population migrates south during autumn and traditionally wintered in salt marshes along the Texas and Louisiana coasts. The snow goose has successfully expanded its winter range into Arkansas, Mississippi, Oklahoma, New Mexico, and northern Mexico, largely because the geese obtain seeds and other food from agricultural lands. Because snow geese have expanded their winter range so successfully, more of the adults survive to return to the Arctic. Their adaptability to human-induced changes in the environment has enabled them to avoid *density-dependent factors* (i.e., lack of food during winter months) that would normally keep the population in check. The huge population of snow geese has damaged much of the Arctic's fragile coastal ecosystem because the geese forage there for a variety of plants and insects (**Figure 16.20**).

HUDSON BAY PROJECT/KRT/Newscom

Figure 16.20 Damage caused by snow geese. The only part of this once-lush salt marsh that survived the onslaught of snow geese was this small patch enclosed in protective fencing to prevent the geese from foraging. The rest of the marsh was reduced to a wasteland. Photographed in northern Manitoba, Canada, along the Hudson Bay.

Wildlife managers want to avoid a massive die-off of geese ıe Arctic, a catastrophe that is unavoidable if the goose ılation is not brought under control. To reduce population bers, U.S. and Canadian wildlife managers have increased 'taking" of snow geese by sport hunters. However, hunting ıot had an appreciable effect on population size, which con- ɜs to grow. Wildlife managers are looking at other options ɜduce the number of snow geese to sustainable levels. For nple, the geese could be commercially harvested for human ɜumption.

ıAGEMENT OF AQUATIC ORGANISMS

ıes with commercial or sport value must be managed to ensure ' are not overexploited to the point of extinction. Freshwa- ishes such as trout and salmon are managed in several ways. ıing laws regulate the time of year, size of fish, and maximum wable catch. Natural habitats are maintained to maximize ulation size. Ponds, lakes, and streams may be restocked with ng hatchlings from hatcheries.

Traditionally, the ocean's resources have been considered ımon property, available to the first people to exploit them. As ɜsult, commercial fishing is severely reducing the number of rine fishes. (Chapter 18 discusses this dwindling resource.)

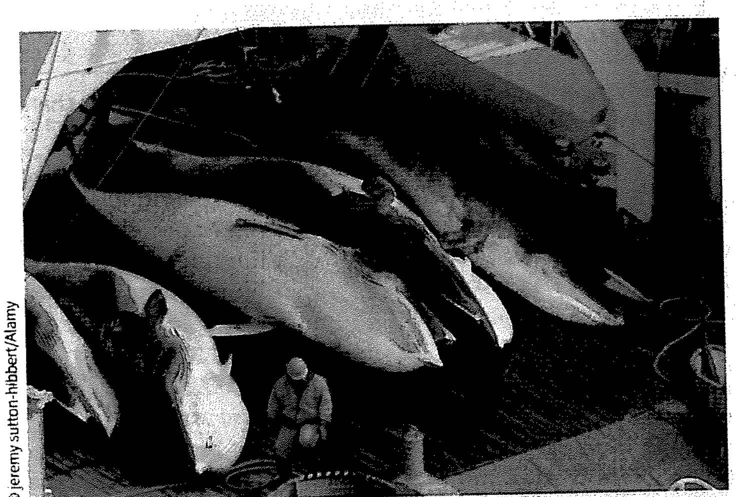
During the 19th and 20th centuries, many whale species were vested to the point of **commercial extinction**, meaning that few remained that it was unprofitable to hunt them. Although nmercially extinct species still have living representatives, their nbers are so reduced that they are endangered. In 1946, the ernational Whaling Commission set an annual limit on killed ales for each whale species in an attempt to secure sustainable ale populations. Unfortunately, these limits were set too high, ulting in further population declines during the next 20 years view the concept of sustainable harvest in Chapter 5). Conser- tionists began to call for a global ban on commercial whaling; ɜh a moratorium went into effect in 1986.

Scientists have since monitored whale populations and con- ıded that overall the ban is working. The populations of most ıales, such as humpbacks and bowheads, seem to be growing. ıe species, the Pacific gray whale, has recovered sufficiently to be removed from the endangered and threatened species lists. The North Atlantic right whale and southern blue whales, however, are still endangered. In 1994, the International Whaling Commission established the Southern Ocean Whale Sanctuary in Antarctic waters, where many of the world's great whales feed and reproduce. This vast sanctuary, which bars commercial hunting, would continue to exist should the current ban on whaling ever be lifted.

Despite international pressure, Japan, Norway, and Iceland do not honor either the global ban on commercial whaling or the Southern Ocean Whale Sanctuary. Japan has justified its continuing whale harvests by saying that the whales are killed for "scientific purposes," although the whale meat from these harvests is sold in Japanese markets and restaurants (**Figure 16.21**).

REVIEW

1. What is wildlife management? How do the goals of wildlife management and conservation biology differ?



© Jeremy sutton-hibbert/Alamy

Figure 16.21 Dead minke whales. These whales were captured in the Southern Ocean and slaughtered ostensibly for research purposes. They are aboard the Japanese research factory ship *Nisshin Maru*.

ENERGY AND CLIMATE CHANGE

Assisted Colonization

ologists have documented that climate warming has caused many ant and animal species to shift their ranges toward the poles or to gher elevations. The ranges of other species have contracted in sponse to climate change, and some species have gone locally tinct. Global climate is expected to continue changing rapidly in the ırrent century, and this fact combined with extensive habitat frag- ıentation of the landscape means that species and even whole eco- ystems will be at risk. It is not known how long various vulnerable pecies can survive in the wild.

Some scientists are considering a highly controversial interven- on called **assisted colonization**, in which species at risk of extinction are moved to areas where they have not been found before. This technique must be done with care, because it is possible that the introduced species could become a pest problem or carry diseases to organisms already living at the new site. In some cases, assisted colonization might not be feasible because no suitable habitat for the at-risk species remains. The cost of assisted colonization could also be prohibitively expensive. Despite the problems, assisted colonization may be the only viable option to reduce the loss of biological diversity from rapid climate change.

REVIEW OF LEARNING OBJECTIVES WITH SELECTED KEY TERMS

- **Define *biological diversity* and distinguish among genetic diversity, species richness, and ecosystem diversity.**

Biological diversity is the number and variety of Earth's organisms; it consists of three components: **genetic diversity** (the variety within a species), **species richness** (the number of species), and **ecosystem diversity** (variety within and among ecosystems).

- **Describe several important ecosystem services provided by biological diversity.**

Ecosystem services are important environmental benefits that ecosystems provide to people. Bacteria and fungi perform the important ecosystem service of decomposition. Forests provide watersheds from which we obtain fresh water. Insects transfer plant pollen for reproduction. Soil organisms maintain soil fertility. Plant roots anchor in the soil and reduce soil erosion.

- **Define *extinction* and distinguish between background extinction and mass extinction.**

Extinction is the elimination of a species from Earth. **Background extinction** is the continuous, low-level extinction of species. **Mass extinctions** are episodes in Earth's history in which numerous species became extinct in a relatively short period.

- **Contrast threatened and endangered species, and list four characteristics common to many endangered species.**

A **threatened species** is a species whose population has declined to the point that it may be at risk of extinction. An **endangered species** is a species that faces threats that may cause it to become extinct within a short period. Endangered and threatened species often have limited natural ranges, low population densities, low reproductive rates, or specialized food or reproduction requirements.

- **Define *biodiversity hotspots* and explain where most of the world's biodiversity hotspots are located.**

Biodiversity hotspots are relatively small areas of land that contain an exceptional number of **endemic** species and are at high risk from human activities. **Norman Myers** and Conservation International have identified 34 biodiversity hotspots around the world; many are tropical, and 10 are mostly or entirely islands.

- **Describe four human causes of species endangerment and extinction, and explain which cause is the most important.**

Habitat destruction is the most significant cause of declining biological diversity because it reduces a species' biological range. **Habitat fragmentation** is a type of habitat destruction in which large areas of habitat are broken into small, isolated patches. Other causes of declining biological diversity are the introduction of foreign species, overexploitation, and pollution.

- **Explain how invasive species endanger native species.**

Invasive species are foreign species that spread rapidly in a new area where they are free of predators, parasites, or resource limitations that may have controlled their population in their native habitat. Invasive species often upset the balance among the organisms living in that area—for example, by competing with native species for food or habitat—and interfere with an ecosystem's normal functioning.

- **Define *conservation biology* and compare in situ and ex situ-conservation.**

Conservation biology is the scientific study of how humans affect organisms and of the development of ways to protect biological diversity. Efforts to preserve biological diversity in nature, called **in situ conservation**, include establishing parks, wildlife sanctuaries and refuges, and other protected areas. **Ex situ conservation**, which includes captive breeding and storing genetic material, occurs in human-controlled settings.

- **Describe restoration ecology.**

Restoration ecology is the study of the historical condition of a human-damaged ecosystem, with the goal of returning it as close as possible to its former state. Restoration ecology is an important part of in situ conservation.

- **Briefly describe the U.S. Endangered Species Act.**

The **Endangered Species Act (ESA)** authorizes the U.S. Fish and Wildlife Service (FWS) to protect from extinction endangered and threatened species, both in the United States and abroad. The FWS selects critical habitats and designs detailed recovery plans for each species listed. **Habitat conservation plans (HCPs)** help resolve ESA conflicts between conservation and development interests on private lands.

- **Distinguish between conservation biology and wildlife management.**

Wildlife management is the application of conservation principles to manage wild species and their habitats for human benefit or for the welfare of other species. In contrast to conservation biology, which often focuses on threatened or endangered species, most attention in wildlife management is focused on common organisms.

Critical Thinking and Review Questions

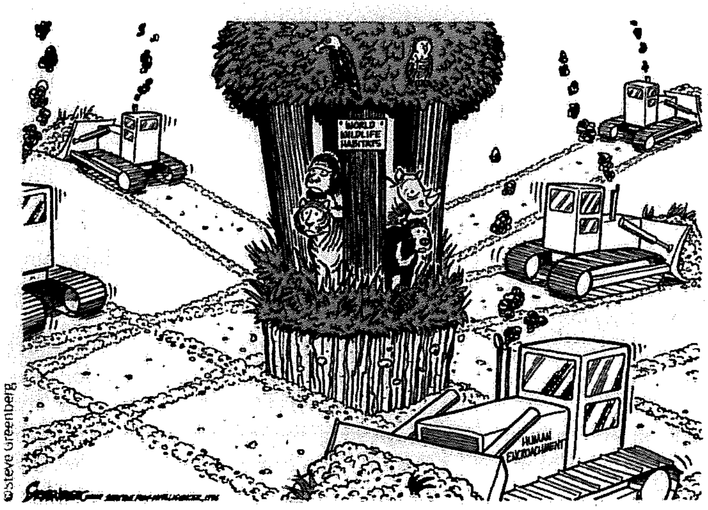
1. Is biological diversity a renewable or nonrenewable resource? Why could it be seen both ways?
2. Aldo Leopold once wrote, "To keep every cog and wheel is the first precaution of intelligent tinkering." How does his statement relate to biological systems? (Aldo Leopold, *A Sand County Almanac.* Oxford University Press, Inc. [1991])
3. Describe five important ecosystem services provided by living organisms.
4. How is the current period of mass extinction different from all previous periods of mass extinction?
5. List four characteristics common to many endangered species.
6. Review the following table and calculate the percent change in number of U.S. threatened or endangered species listed between 2005 and 2014, both total and for each group. What is the total percent change? Which groups of organisms have experienced the greatest declines? Suggest reasons for these trends.

U.S. Organisms Listed as Endangered or Threatened, 2005–2014

Type of organism	*2005*	*2014*
Mammals	78	90
Birds	90	97
Reptiles	36	36
Amphibians	21	31
Fishes	114	154
Insects	44	70
Clams	70	88
Flowering plants	715	839
Other plants and animals	96	119
Total	1264	1524

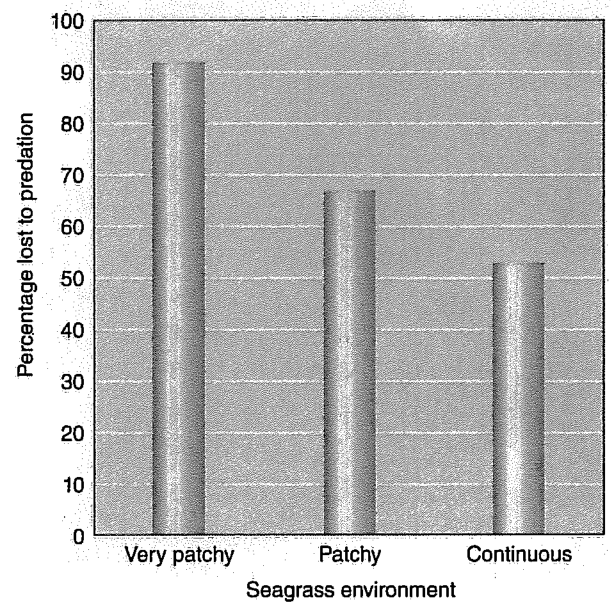
Data from U.S. Fish and Wildlife Service

7. What are biodiversity hotspots? Why are so many of them isolated?
8. According to the cartoon, what is one of the main causes of habitat loss in terrestrial ecosystems?



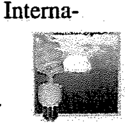
©Steve Greenberg

9. What invasive species are problems in your area? How do they affect local ecosystems, including native species? How are the invasive species being controlled?
10. Give examples of in situ and ex situ conservation.
11. The following graph shows the effects of predation over a four-week period on young bay scallops in three different marine seagrass environments. How does habitat fragmentation (patchiness) affect the percentage of young bay scallops lost to predation? Suggest a possible reason for this effect.



(After data from E.A. Irlandi, W.G. Ambrose, and B.A. Orando, "Landscape Ecology and the Marine Environment: How Spatial Configuration of Seagrass Habitat Influences Growth and Survival of the Bay Scallop," *Oikos* 72 [1995].)

12. If you had the assets and authority to take any measure to protect and preserve biological diversity but could take only one, what would it be?
13. What are two advantages of using the principles of restoration ecology to return a degraded environment to a more functional one? How can these be applied to small, local sites?
14. What U.S. law provides legal protection to species to reduce their danger of extinction? How are scientific considerations and economic value weighed in these listings? Explain your answer.
15. Why is the Arctic snow goose such a challenge for U.S. wildlife managers? For Canadian wildlife managers?
16. When people discuss the impact of global climate change, they usually mention polar bears or other charismatic animals. However, according to scientists at Botanic Gardens Conservation International, half of all plant species could be threatened by climate change. Most of these plants live on islands or mountains. Offer an explanation for why this is the case.



Food for Thought

The quest for food in the United States has resulted in many dramatic changes to our natural landscapes. In what ways has agriculture contributed to species endangerment and to habitat damage and destruction? How might the wildlife in your town or region have been affected by agricuature? Consider some approaches that food producers might take to avoid these historical effects. How might a backyard gardener protect species and habitats?