Sustaining Biodiversity: The Species Approach

9

The Passenger Pigeon: Gone Forever

CORE CASE STUDY

In 1813, bird expert John James Audubon saw a single huge flock of passenger pigeons that took three days to fly past him and was so dense that it darkened the skies.

By 1900, North America's passenger pigeon (Figure 9-1), once the most numerous bird species on earth, had disappeared from the wild because of a combination of uncontrolled commercial hunting and habitat loss as forests were cleared to make room for farms and cities. These birds were good to eat, their feathers made good pillows, and their bones were widely used for fertilizer. They were easy to kill because they flew in gigantic flocks and nested in long, narrow, densely packed colonies.

Commercial hunters would capture one pigeon alive, sew its eyes shut, and tie it to a perch called a stool. Soon a curious flock would land beside this "stool pigeon"—a term we now use to describe someone who turns in another person for breaking the law. Then the birds would be shot or ensnared by nets that could trap more than 1,000 of them at once.

Beginning in 1858, passenger pigeon hunting became a big business. Shotguns, traps, artillery, and even dynamite were used. People burned grass or sulfur below their roosts to suffocate the birds. Shooting galleries used live birds as targets. In 1878, one professional pigeon trapper made $60,000 by killing 3 million birds at their nesting grounds near Petoskey, Michigan.

By the early 1880s, only a few thousand birds remained. At that point, recovery of the species was doomed because the females laid only one egg per nest each year. On March 24, 1900, a young boy in the U.S. state of Ohio shot the last known wild passenger pigeon.

Eventually all species become extinct or evolve into new species. The archeological record reveals five *mass extinctions* since life on the earth began—each a massive impoverishment of life on the earth. These mass extinctions were caused by natural phenomena, such as major climate change or large asteroids hitting the earth, which drastically altered the earth's environmental conditions.

There is considerable evidence that we are now in the early stage of a sixth great extinction. Evidence indicates that we humans are causing this mass extinction as our population grows and as we consume more resources, disturb more land and aquatic systems, use more of the earth's net primary productivity, and cause changes to the earth's climate.

Scientists project that during this century, human activities, especially those that cause habitat destruction and climate change, will lead to the premature extinction of one-fourth to one-half of the world's plant and animal species—an incredibly rapid rate of extinction. And there will be no way to restore what we have lost, because species extinction is forever. If we keep impoverishing the earth's biodiversity, eventually, our species will also become impoverished.

Michael Sewell/Peter Arnold, Inc.

Figure 9-1 Lost natural capital: passenger pigeons have been extinct in the wild since 1900 because of human activities. The last known passenger pigeon died in the U.S. state of Ohio's Cincinnati Zoo in 1914.

Key Questions and Concepts

9-1 What role do humans play in the premature extinction of species?

CONCEPT 9-1A We are degrading and destroying biodiversity in many parts of the world, and these threats are increasing.

CONCEPT 9-1B Species are becoming extinct 100 to 1,000 times faster than they were before modern humans arrived on the earth (the *background rate*), and by the end of this century, the extinction rate is expected to be 10,000 times the background rate.

9-2 Why should we care about preventing premature species extinction?

CONCEPT 9-2 We should prevent the premature extinction of wild species because of the economic and ecological services they provide and because they have a right to exist regardless of their usefulness to us.

9-3 How do humans accelerate species extinction?

CONCEPT 9-3 The greatest threats to any species are (in order) loss or degradation of its habitat, harmful invasive species, human population growth, pollution, climate change, and overexploitation.

9-4 How can we protect wild species from extinction resulting from our activities?

CONCEPT 9-4A We can use existing environmental laws and treaties and work to enact new laws designed to prevent premature species extinction and protect overall biodiversity.

CONCEPT 9-4B We can help to prevent premature species extinction by creating and maintaining wildlife refuges, gene banks, botanical gardens, zoos, and aquariums.

CONCEPT 9-4C According to the *precautionary principle*, we should take measures to prevent or reduce harm to the environment and to human health, even if some of the cause-and-effect relationships have not been fully established, scientifically.

Note: Supplements 2 (p. S4), 4 (p. S20), 9 (p. S53), and 13 (p. S78) can be used with this chapter.

The last word in ignorance is the person who says of an animal or plant:
"What good is it?" . . . If the land mechanism as a whole is good,
then every part of it is good, whether we understand it or not. . . .
Harmony with land is like harmony with a friend;
you cannot cherish his right hand and chop off his left.

ALDO LEOPOLD

9-1 What Role Do Humans Play in the Premature Extinction of Species?

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Human Activities Are Destroying and Degrading Biodiversity

We have depleted and degraded some of the earth's biodiversity, and these threats are expected to increase (**Concept 9-1A**). According to biodiversity expert Edward O. Wilson, "The natural world is everywhere disappearing before our eyes—cut to pieces, mowed down, plowed under, gobbled up, replaced by human artifacts."

According to the 2005 Millennium Ecosystem Assessment and other studies, humans have disturbed, to some extent, at least half and probably about 83% of the earth's land surface (excluding Antarctica and Greenland; see Figure 3, pp. S24–S25, in Supplement 4). Most of this disturbance involves filling in wetlands or converting grasslands and forests to crop fields and urban areas. Such disturbances eliminate large numbers of species by destroying or degrading their habitats, as discussed in more detail in Chapter 10.

Links: CORE CASE STUDY refers to the Core Case Study. SUSTAINABILITY refers to the book's sustainability theme. CONCEPT LINK indicates links to key concepts in earlier chapters.

Human activities are also degrading the earth's *aquatic biodiversity*, as discussed in Chapter 11.

Extinctions Are Natural but Sometimes They Increase Sharply

In due time, all species become extinct. During most of the 3.56 billion years that life has existed on the earth, there has been a continuous, low level of extinction of species known as **background extinction.**

An **extinction rate** is expressed as a percentage or number of species that go extinct within a certain time period such as a year. For example, one extinction per million species per year would be 1/1,000,000 = 0.000001 species per year. Expressed as a percentage, this is 0.000001 × 100, or 0.0001%—the estimated *background extinction rate* existing before humans came on the scene.

The balance between formation of new species and extinction of existing species determines the earth's biodiversity (**Concept 4-4A**, p. 86). Overall, the earth's biodiversity has increased for several hundred million years, except during a few periods. The extinction of many species in a relatively short period of geologic time is called a **mass extinction.** Geological and other records indicate that the earth has experienced five mass extinctions when 50–95% of the world's species appear to have become extinct. After each mass extinction, biodiversity eventually returned to equal or higher levels, but each recovery required millions of years.

CONCEPT LINK

The causes of past mass extinctions are poorly understood but probably involved global changes in environmental conditions. Examples are major climate change or a large-scale catastrophe such as a collision between the earth and a comet or large asteroid. The last of these mass extinctions took place about 65 million years ago. One hypothesis is that the last mass extinction taking place about 65 million years ago occurred after a large asteroid hit the planet and spewed huge amounts of dust and debris into the atmosphere. This could have reduced the input of solar energy and cooled the planet enough to wipe out the dinosaurs and many other forms of earth's life at that time.

Biologists distinguish among three levels of species extinction. *Local extinction* occurs when a species is no longer found in an area it once inhabited but is still found elsewhere in the world. Most local extinctions involve losses of one or more populations of species. *Ecological extinction* occurs when so few members of a species are left that it can no longer play its ecological roles in the biological communities where it is found.

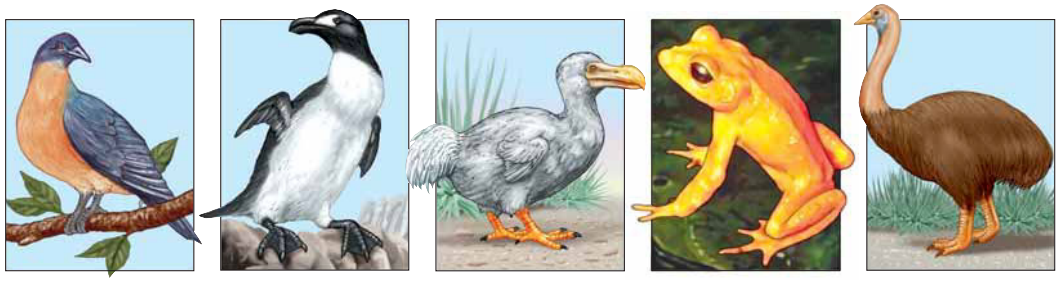
In *biological extinction*, a species, such as the passenger pigeon (**Core Case Study**, Figure 9-1) is no longer found anywhere on the earth. Biological extinction is forever and represents an irreversible loss of natural capital.

CORE CASE STUDY

Some Human Activities Cause Premature Extinctions, and the Pace Is Speeding Up

Although extinction is a natural biological process, it has accelerated as human populations have spread over the globe, consuming large quantities of resources, and creating large ecological footprints (Figure 1-10, p. 15). As a result, human activities are destroying the earth's biodiversity at an unprecedented and accelerating rate. Figure 9-2 shows a few of the many species that have become prematurely extinct mostly because of human activities.

Using the methods described in the Science Focus box (p. 188), scientists from around the world, who published the 2005 Millennium Ecosystem Assessment, estimated that the current annual rate of species extinction is at least 100 to 1,000 times the background rate of about 0.0001%, which existed before modern humans appeared some 150,000 years ago. This amounts to an extinction rate of 0.01% to 0.1% a year. Conservation biologists project that during this century the extinction rate caused by habitat loss, climate change mostly due to global warming, and other



Passenger pigeon | Great auk | Dodo | Golden toad | Aepyornis (Madagascar)

Figure 9-2 Lost natural capital: some animal species that have become prematurely extinct largely because of human activities, mostly habitat destruction and overhunting. **Question:** Why do you think birds top the list of extinct species?

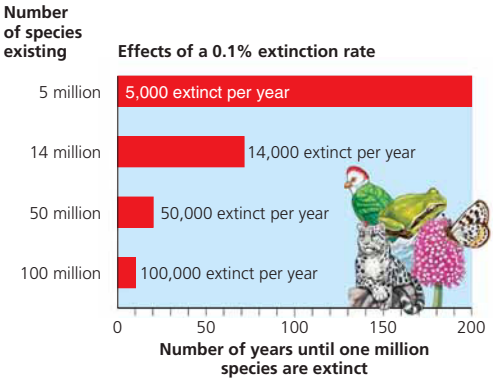


Figure 9-3 Effects of a 0.1% extinction rate.

human activities will increase to 10,000 times the background rate (**Concept 9-1B**). This will amount to an annual extinction rate of 1% per year.

How many species are we losing prematurely each year? The answer depends on how many species are on the earth and the rate of species extinction. Assuming that the extinction rate is 0.1%, each year we lose 5,000 species if there are 5 million species on earth and 14,000 species if there are 14 million species—the current best scientific estimate. See Figure 9-3 for more examples.

According to researchers Edward O. Wilson and Stuart Pimm, at a 1% extinction rate, at least one-fourth of the world's current animal and plant species could be gone by 2050 and half could vanish by the end of this century. In the words of biodiversity expert Norman Myers, "Within just a few human generations, we shall—in the absence of greatly expanded conservation efforts—impoverish the biosphere to an extent that will persist for at least 200,000 human generations or twenty times longer than the period since humans emerged as a species."

THINKING ABOUT
Extinction

How might your lifestyle change if human activities cause the premature extinction of up to half of the world's species in your lifetime? List three aspects of your lifestyle that contribute to this threat to the earth's natural capital.

Most extinction experts consider extinction rates of 0.01–1% to be conservative estimates (**Concept 9-1B**) for several reasons. *First,* both the rate of species loss and the extent of biodiversity loss are likely to increase during the next 50–100 years because of the projected growth of the world's human population and resource use per person (Figure 1-10, p. 15, and Figure 3, pp. S24–S25, in Supplement 4) and climate change caused mostly by global warming.

Second, current and projected extinction rates are much higher than the global average in parts of the world that are highly endangered centers of biodiversity. Conservation biologists urge us to focus our efforts on slowing the much higher rates of extinction in such *hotspots* as the best and quickest way to protect much of the earth's biodiversity from being lost prematurely. (We discuss this further in Chapter 10.)

Third, we are eliminating, degrading, fragmenting, and simplifying many biologically diverse environments—such as tropical forests, tropical coral reefs, wetlands, and estuaries—that serve as potential colonization sites for the emergence of new species (**Concept 4-4B**, p. 86). Thus, in addition to increasing the rate of extinction, we may be limiting the long-term recovery of biodiversity by reducing the rate of speciation for some species. In other words, we are creating a *speciation crisis.* (See the Guest Essay by Normal Myers on this topic at CengageNOW™.)

CONCEPT LINK

Philip Levin, Donald Levin, and other biologists also argue that the increasing fragmentation and disturbance of habitats throughout the world may increase the speciation rate for rapidly reproducing opportunist species such as weeds, rodents, and cockroaches and other insects. Thus, the real threat to biodiversity from current human activities may be long-term erosion in the earth's variety of species and habitats. Such a loss of biodiversity would reduce the ability of life to adapt to changing conditions by creating new species.

Endangered and Threatened Species Are Ecological Smoke Alarms

Biologists classify species heading toward biological extinction as either *endangered* or *threatened.* An **endangered species** has so few individual survivors that the species could soon become extinct over all or most of its natural range (the area in which it is normally found). Like the passenger pigeon (**Core Case Study,** Figure 9-1) and several other bird species (Figure 9-2), they may soon disappear from the earth. A **threatened species** (also known as a vulnerable species) is still abundant in its natural range but, because of declining numbers, is likely to become endangered in the near future.

CORE CASE STUDY

The International Union for the Conservation of Nature and Natural Resources (IUCN)—also known as the World Conservation Union—is a coalition of the world's leading conservation groups. Since the 1960s, it has published annual *Red Lists,* which have become the world standard for listing the world's threatened species. In 2007, the list included 16,306 plants and animals that are in danger of extinction—60% higher than the number listed in 1995. Those compiling the list say it greatly underestimates the true number of threatened species because only a tiny fraction of 1.8 million known species have been assessed, and of the estimated total of 4–100 million additional species that have not been catalogued or studied. You can examine the Red Lists database online at **www.iucnredlist.org**. Figure 9-4 shows a few of the roughly 1,300 species

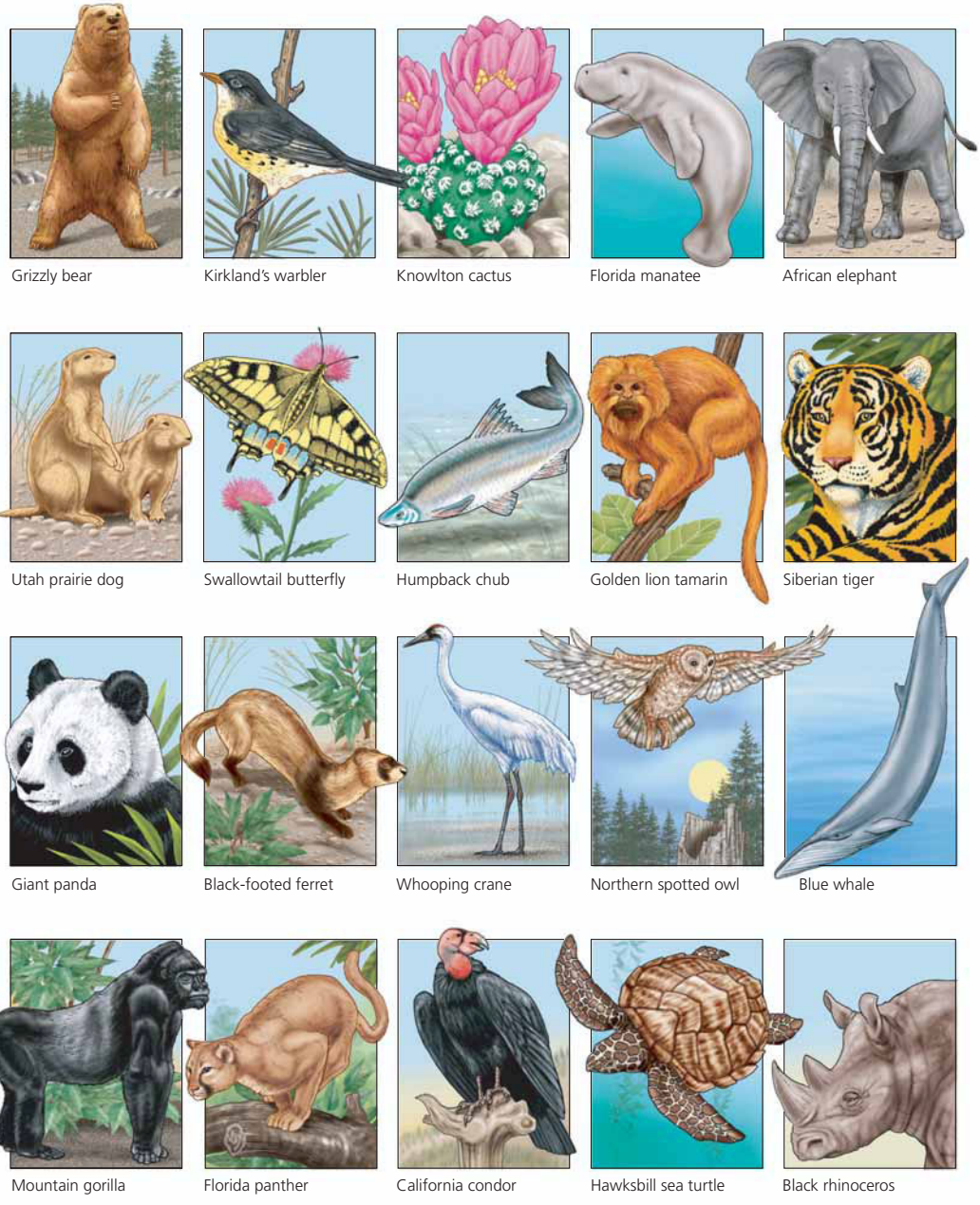


Figure 9-4 **Endangered natural capital:** some species that are endangered or threatened with premature extinction largely because of human activities. Almost 30,000 of the world's species and roughly 1,300 of those in the United States are officially listed as being in danger of becoming extinct. Most biologists believe the actual number of species at risk is much larger.

SCIENCE FOCUS

Estimating Extinction Rates Is Not Easy

Conservation biologists who are trying to catalog extinctions, estimate past extinction rates, and project future rates have three problems. *First,* the extinction of a species typically takes such a long time that it is not easy to document. *Second,* we have identified only about 1.8 million of the world's estimated 4 million to 100 million species. *Third,* scientists know little about the nature and ecological roles of most of the species that have been identified.

One approach to estimating future extinction rates is to study records documenting the rates at which mammals and birds (which have been the easiest to observe) have become extinct since humans arrived and to compare this with fossil records of extinctions prior to the arrival of humans. Determining the rates at which minor DNA copying mistakes occur can help scientists to track how long various species typically last before becoming extinct. Such evidence indicates that under normal circumstances, species survive for 1 million to 10 million years before going extinct.

Another approach is to observe how the number of species present increases with the size of an area. This *species–area relationship* suggests that, on average, a 90% loss of habitat causes the extinction of 50% of the species living in that habitat. This is based on the *theory of island biogeography* (Science Focus, p. 90). Scientists use this model to estimate the number of current and future extinctions in patches or "islands" of shrinking habitat surrounded by degraded habitats or by rapidly growing human developments.

Scientists also use mathematical models to estimate the risk of a particular species becoming endangered or extinct within a certain period of time. These models include factors such as trends in population size, changes in habitat availability, interactions with other species, and genetic factors. Researchers know that their estimates of extinction rates are based on insufficient data and sampling and incomplete models. They are continually striving to get more data and to improve the models used to estimate extinction rates.

At the same time, they point to clear evidence that human activities have accelerated the rate of species extinction and that this rate is still increasing. According to these biologists, arguing over the numbers and waiting to get better data and models should not be used as excuses for inaction. They agree with the advice of Aldo Leopold (Individuals Matter, p. 22) in his thoughts about preventing premature extinction: "To keep every cog and wheel is the first precaution of intelligent tinkering."

Critical Thinking

How would you improve the estimation of extinction rates?

officially listed as endangered and protected under the U.S. Endangered Species Act.

Some species have characteristics that make them especially vulnerable to ecological and biological extinction (Figure 9-5). As biodiversity expert Edward O. Wilson puts it, "The first animal species to go are the big, the slow, the tasty, and those with valuable parts such as tusks and skins."

Some species also have *behavioral characteristics* that make them prone to extinction. The passenger pigeon (**Core Case Study**, Figure 9-1) and the Carolina parakeet nested in large flocks that made them easy to kill. Key deer, which live only in the U.S. Florida Keys, are "nicotine addicts" that get killed by cars because they forage for cigarette butts along highways. Some types of species are more threatened with premature extinction from human activities than others are (Figure 9-6).

CORE CASE STUDY

RESEARCH FRONTIER

Identifying and cataloguing the millions of unknown species and improving models for estimating extinction rates. See **academic.cengage.com/biology/miller**.

Figure 9-5 Characteristics of species that are prone to ecological and biological extinction. **Question:** Which of these characteristics helped lead to the premature extinction of the passenger pigeon within a single human lifetime?

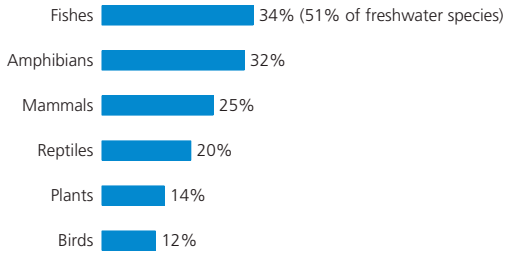


Figure 9-6 Endangered natural capital: percentage of various types of species threatened with premature extinction because of human activities (**Concept 9-1A**). **Question:** Why do you think fishes top this list? (Data from World Conservation Union, Conservation International, World Wide Fund for Nature, 2005 Millennium Ecosystem Assessment, and the Intergovernmental Panel on Climate Change)

9-2 Why Should We Care about Preventing Premature Species Extinction?

CONCEPT 9-2 We should prevent the premature extinction of wild species because of the economic and ecological services they provide and because they have a right to exist regardless of their usefulness to us.

Species Are a Vital Part of the Earth's Natural Capital

So what is all the fuss about? If all species eventually become extinct, why should we worry about premature extinctions? Does it matter that the passenger pigeon (**Core Case Study**) became prematurely extinct because of human activities, or that the remaining orangutans (Figure 9-7) or some unknown plant or insect in a tropical forest might suffer the same fate?

CORE CASE STUDY

New species eventually evolve to take the places of those lost through mass extinctions. So why should we care if we speed up the extinction rate over the next 50–100 years? The answer: because it will take 5–10 million years for natural speciation to rebuild the biodiversity we are likely to destroy during your lifetime.

Biodiversity researchers say we should act now to prevent premature extinction of species partly for their **instrumental value**—their usefulness to us in providing many of the ecological and economic services that

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Figure 9-7 Natural capital degradation: endangered orangutans in a tropical forest. In 1900, there were over 315,000 wild orangutans. Now there are less than 20,000 and they are disappearing at a rate of over 2,000 per year because of illegal smuggling and clearing of their forest habitat in Indonesia and Malaysia to make way for oil palm plantations. An illegally smuggled orangutan typically sells for a street price of $10,000. According to 2007 study by the World Wildlife Fund (WWF), projected climate change will further devastate remaining orangutan populations in Indonesia and Malaysia. **Question:** How would you go about trying to set a price on the ecological value of an orangutan?

make up the earth's natural capital (Figure 1-3, p. 8) (**Concept 9-2**).

Instrumental values take two forms. One is *use values,* which benefit us in the form of economic goods and services, ecological services, recreation, scientific information, and the continuation of such uses for future generations. Each year, Americans, as a whole, spend more than three times as many hours watching wildlife—doing nature photography and bird watching, for example—as they spend watching movies or professional sporting events. A diversity of plant species provides economic value in the form of food crops, fuelwood, lumber, paper, drugs, and medicines (Figure 9-8). Bioprospectors search tropical forests and other ecosystems for plants and animals that have chemicals that can be converted into useful medicinal drugs. A 2005 United Nations University report concluded that 62% of all cancer drugs were derived from the discoveries of bioprospectors. **GREEN CAREER:** Bioprospecting

Species diversity also provides economic benefits from wildlife tourism, or *ecotourism,* which generates between $950,000 and $1.8 million per minute in tourist expenditures worldwide. Conservation biologist Michael Soulé estimates that one male lion living to age 7 generates $515,000 in tourist dollars in Kenya, but only $1,000 if killed for its skin. Similarly, over a lifetime of 60 years, a Kenyan elephant is worth about $1 million in ecotourist revenue—many times more than its tusks are worth when they are sold illegally for their ivory (Science Focus, at right). Ecotourism should not cause ecological damage, but some of it does. The website for this chapter lists some guidelines for evaluating eco-tours. **GREEN CAREER:** Ecotourism guide

Another instrumental value is the *genetic information* that allows species to adapt to changing environmental conditions through evolution. Genetic engineers use this information to produce genetically modified crops and foods. Scientists warn of the alarming loss of genetic diversity resulting from our increasing reliance on a small number of crop plants for feeding the world. Such a loss also results from the premature extinction of wild plants whose genes could be used by genetic engineers to develop improved crop varieties.

One of the tragedies of the current extinction crisis is that we do not know what we are losing, because no one has ever seen or named many of the species that are becoming extinct. Consequently, we know nothing about their genetic makeup, their roles in sustaining ecosystems, or how they might be used to improve human welfare. Carelessly eliminating many of the species that make up the world's vast genetic library is like burning books that we have never read.

The other major form of instrumental value is *nonuse values,* of which there are several types. For example, there is *existence value*—the satisfaction of knowing that a redwood forest, a wilderness, orangutans (Figure 9-7), and wolf packs exist, even if we will never see them or get direct use from them. For many people, biodiversity holds *aesthetic value.* For example, we can appreciate a tree, an orangutan, or a tropical bird (Figure 9-9) for its beauty. A third type is *bequest value,*

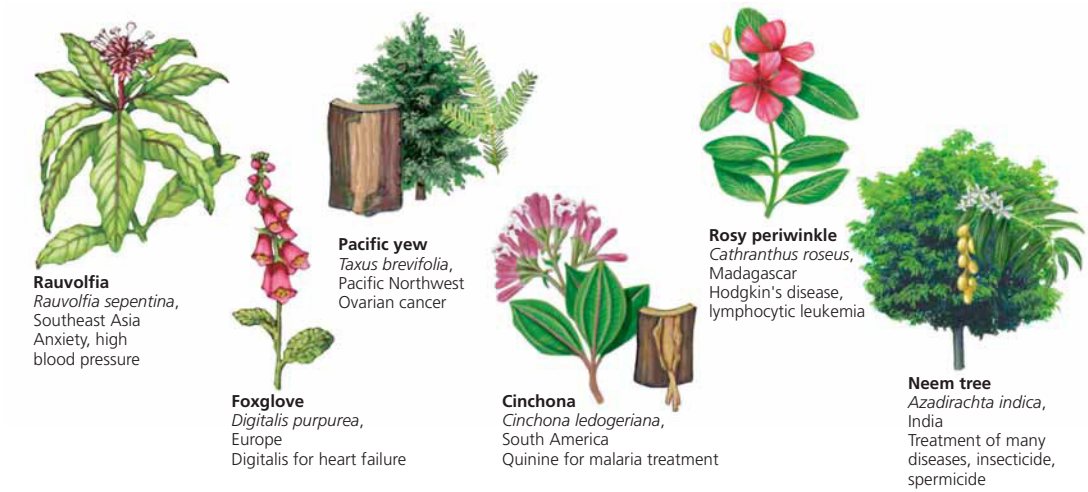

Figure 9-8 Natural capital: *nature's pharmacy.* Parts of these and a number of other plant and animal species (many of them found in tropical forests) are used to treat a variety of human ailments and diseases. Nine of the ten leading prescription drugs originally came from wild organisms. About 2,100 of the 3,000 plants identified by the National Cancer Institute as sources of cancer-fighting chemicals come from tropical forests. Despite their economic and health potential, fewer than 1% of the estimated 125,000 flowering plant species in tropical forests (and a mere 1,100 of the world's 260,000 known plant species) have been examined for their medicinal properties. Once the active ingredients in the plants have been identified, they can usually be produced synthetically. Many of these tropical plant species are likely to become extinct before we can study them.

Using DNA to Reduce Illegal Killing of Elephants for Their Ivory

There are about 400,000 elephants remaining in the wild, most of them in Africa and the rest in Asia. Elephants have long been valued for the ivory in their tusks, but in 1989, an international treaty instituted a ban on the trading of such ivory.

Before the 1989 treaty, poachers slaughtered about 87,000 elephants a year for their ivory. Although this treaty reduced the poaching, it did not stop it. In recent years, the illegal slaughter of elephants for ivory has increased again to about 25,000 a year, most of it in the African countries of Cameroon, Nigeria, and Democratic Republic of the Congo. This poaching has risen sharply since 2004, fueled by sharply rising prices of high-quality ivory, mostly in China. Because of the money to be made, organized crime has become more heavily involved in this illegal trade.

In 2007, scientists began developing a DNA-based map of elephant populations that allows them to use DNA analysis of seized illegal ivory to determine where the elephants were killed. They hope to use such data to identify poaching hot spots and help international law enforcement authorities to focus their anti-poaching efforts.

On the other hand, elephant populations have exploded in some areas, such as parts of South Africa, and are destroying vegetation and affecting the populations of other species.

A single adult elephant devours up to 300 kilograms (660 pounds) of grass, leaves, and twigs a day. Elephants can also uproot trees and disturb the soil. The South African government is considering killing (culling) enough elephants each year to keep the population down in selected areas. The culled ivory would be sold in the international marketplace with the proceeds used to benefit the populations of local villagers and to help pay for conservation efforts. DNA analysis could be used to distinguish such culled ivory from poached ivory.

Supporters say that increasing the amount of ivory legally available in the marketplace could help to reduce poaching by lowering market prices. Some animal rights groups oppose elephant culling on ethical grounds.

Critical Thinking

Do you favor culling elephants in areas where large populations are degrading vegetation? Explain.

based on the fact that people will pay to protect some forms of natural capital for use by future generations.

Finally, species diversity holds *ecological value,* because it is a vital component of the key ecosystem functions of energy flow, nutrient cycling (Figure 3-12, p. 60), and population control, in keeping with three of the four **scientific principles of sustainability** (see back cover). In other words, the species in ecosystems provide essential *ecosystem* or *natural services,* an important component of the natural capital (Figure 1-3, p. 8, orange items) that supports and sustains the earth's life and economies. Thus, in protecting species from premature extinction and in protecting their vital habitats from environmental degradation (as we discuss in the next chapter), we are helping to sustain our own health and well-being.

Are We Ethically Obligated to Prevent Premature Extinction?

Some scientists and philosophers believe that each wild species has **intrinsic** or **existence value** based on its inherent right to exist and play its ecological roles, regardless of its usefulness to us (**Concept 9-2**). According to this view, we have an ethical responsibility to protect species from becoming prematurely extinct as a result of human activities and to prevent the degradation of the world's ecosystems and its overall biodiversity.

Each species in the encyclopedia of life is a masterpiece of evolution that possesses a unique combination

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Figure 9-9 Many species of wildlife, such as this endangered scarlet macaw in Brazil's Amazon rain forest, are a source of beauty and pleasure. These and other colorful species of parrots can become endangered when they are removed from the wild and sold (sometimes illegally) as pets.

SCIENCE FOCUS

Why Should We Care about Bats?

Worldwide there are 950 known species of bats—the only mammals that can fly. But bats have two traits that make them vulnerable to extinction. *First,* they reproduce slowly. *Second,* many bat species live in huge colonies in caves and abandoned mines, which people sometimes close up. This prevents them from leaving to get food, or it can interrupt their hibernation if they have to leave their shelter to escape being trapped.

Bats play important ecological roles. About 70% of all bat species feed on crop-damaging nocturnal insects (Figure 5-3, p. 105) and other insect pest species such as mosquitoes. This makes them the major nighttime SWAT team for such insects.

In some tropical forests and on many tropical islands, *pollen-eating bats* pollinate flowers, and *fruit-eating bats* distribute plants throughout these forests by excreting undigested seeds. As keystone species, such bats are vital for maintaining plant biodiversity and for regenerating large areas of tropical forest that has been cleared by humans. If you enjoy bananas, cashews, dates, figs, avocados, or mangos, you can thank bats.

Many people mistakenly view bats as fearsome, filthy, aggressive, rabies-carrying bloodsuckers. But most bat species are harmless to people, livestock, and crops. In the United States, only 10 people have died of bat-transmitted disease in more than 4 decades of record keeping; more Americans die each year from being hit by falling coconuts.

Because of unwarranted fears of bats and lack of knowledge about their vital ecological roles, several bat species have been driven to extinction. Currently, about one-fourth of the world's bat species are listed as endangered or threatened. And thousands of bats are dying from an unknown illness in the northeastern United States. Because of the important ecological and economic roles they play, conservation biologists urge us to view bats as valuable allies, not as enemies to kill.

Critical Thinking

Has reading this material changed your view of bats? Can you think of two things that could be done to help protect bat species from premature extinction?

of genetic traits. These traits allow a species to become adapted to its natural environment and to changing environmental conditions through natural selection. Many analysts believe that we have no right to prematurely erase these unique genetic packages. On this basis, we have an ethical obligation to control our resource consumption to help protect all species, which make up a key component of the earth's biodiversity (Figure 4-2, p. 79), and in the process implement one of the four **scientific principles of sustainability** (see back cover).

Biologist Edward O. Wilson contends that because of the billions of years of biological connections leading to the evolution of the human species, we have an inherent genetic kinship with the natural world. He calls this phenomenon *biophilia* (love of life).

Evidence of this natural and emotional affinity for life is seen in the preference most people have for almost any natural scene over one from an urban environment. Given a choice, most people prefer to live in an area where they can see water and natural landscapes, such as a grassland or a forest. They also have an affinity for parks, wildlife, and pets and enjoy birdwatching, hiking, camping, fishing, and other outdoor activities. More people visit zoos and aquariums than attend all professional sporting events combined.

Some have the opposite feeling—a fear of many forms of wildlife—called *biophobia.* For example, some movies, books, and TV programs condition us to fear or be repelled by certain species such as alligators (Chapter 4 Core Case Study, p. 77), cockroaches (Case Study, p. 92), sharks (Case Study, p. 96), bats (Science Focus above), and bacteria (Science Focus, p. 61). Many people have lived so long in artificial urban settings that they are largely disconnected from wildlife and from outdoor experiences in nature.

Some people distinguish between the survival rights of plants and those of animals, mostly for practical reasons. Poet Alan Watts once said he was a vegetarian "because cows scream louder than carrots."

Other people distinguish among various types of species. For example, they might think little about getting rid of the world's mosquitoes, cockroaches, rats, or disease-causing bacteria, but feel protective of panda bears, elephants, and whales.

THINKING ABOUT

The Passenger Pigeon

CORE CASE STUDY

In earlier times, many people viewed huge flocks of passenger pigeons (**Core Case Study**) as pests that devoured grain and left massive piles of their waste. Do you think this justified the passenger pigeon's premature extinction? Explain. If you believe that premature extinction of an undesirable species is justified, what would be your three top candidates? What might be some harmful ecological effects of such extinctions?

Some biologists caution us not to focus primarily on protecting relatively large organisms—the plants and animals we can see that are familiar to us. They remind us that the true foundation of the earth's ecosystems and ecological processes is made up of invisible bacteria and the algae, fungi, and other *microorganisms* that decompose the bodies of larger organisms and recycle the nutrients needed by all life.

9-3 How Do Humans Accelerate Species Extinction?

CONCEPT 9-3 **The greatest threats to any species are (in order) loss or degradation of its habitat, harmful invasive species, human population growth, pollution, climate change, and overexploitation.**

Loss of Habitat Is the Single Greatest Threat to Species: Remember HIPPCO

Figure 9-10 shows the underlying and direct causes of the endangerment and premature extinction of wild species. Conservation biologists summarize the most important causes of premature extinction using the acronym **HIPPCO: H**abitat destruction, degradation, and fragmentation; **I**nvasive (nonnative) species; **P**opulation and resource use growth (too many people consuming too many resources); **P**ollution; **C**limate change; and **O**verexploitation (**Concept 9-3**).

According to biodiversity researchers, the greatest threat to wild species is habitat loss (Figure 9-11, p. 194), degradation, and fragmentation. The passenger pigeon (**Core Case Study**, Figure 9-1) is only one of many species whose extinction was hastened by loss of habitat from forest clearing.

CORE CASE STUDY

Deforestation in tropical areas (Figure 3-1, p. 50) is the greatest eliminator of species, followed by the destruction and degradation of coral reefs and wetlands, plowing of grasslands, and pollution of streams, lakes, and oceans. Globally, temperate biomes have been affected more by habitat loss and degradation than have tropical biomes because of widespread economic development in temperate countries over the past 200 years. Such development is now shifting to many tropical biomes.

Island species—many of them *endemic species* found nowhere else on earth—are especially vulnerable to extinction when their habitats are destroyed, degraded, or fragmented. This is why the collection of islands that make up the U.S. state of Hawaii are America's "extinction capital" —with 63% of its species at risk.

Any habitat surrounded by a different one can be viewed as a *habitat island* for most of the species that live there. Most national parks and other nature reserves are habitat islands, many of them encircled by potentially damaging logging, mining, energy extraction, and industrial activities. Freshwater lakes are also habitat islands that are especially vulnerable to the introduction of nonnative species and pollution.

Habitat fragmentation—by roads, logging, agriculture, and urban development—occurs when a large,

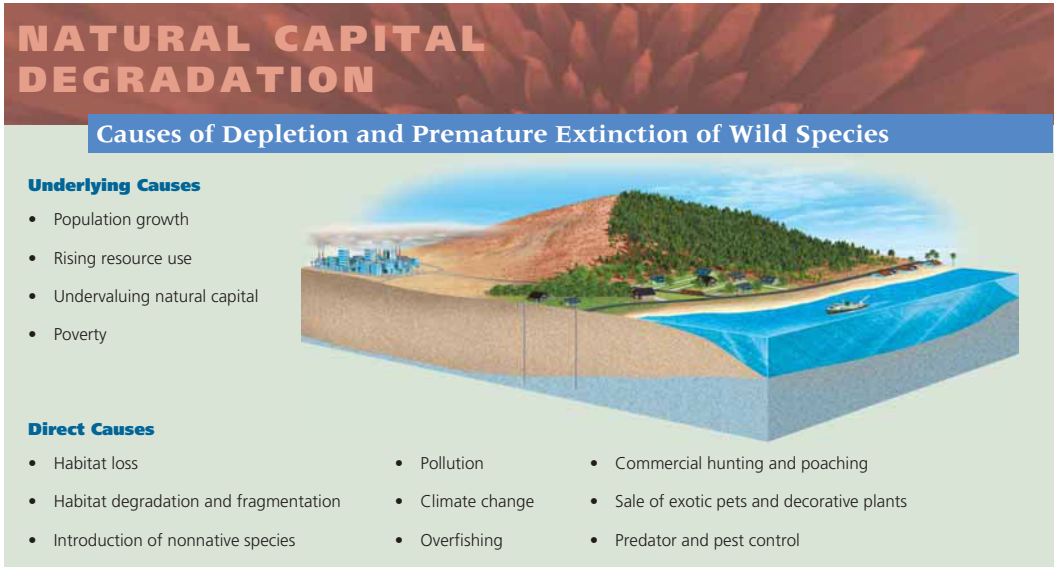
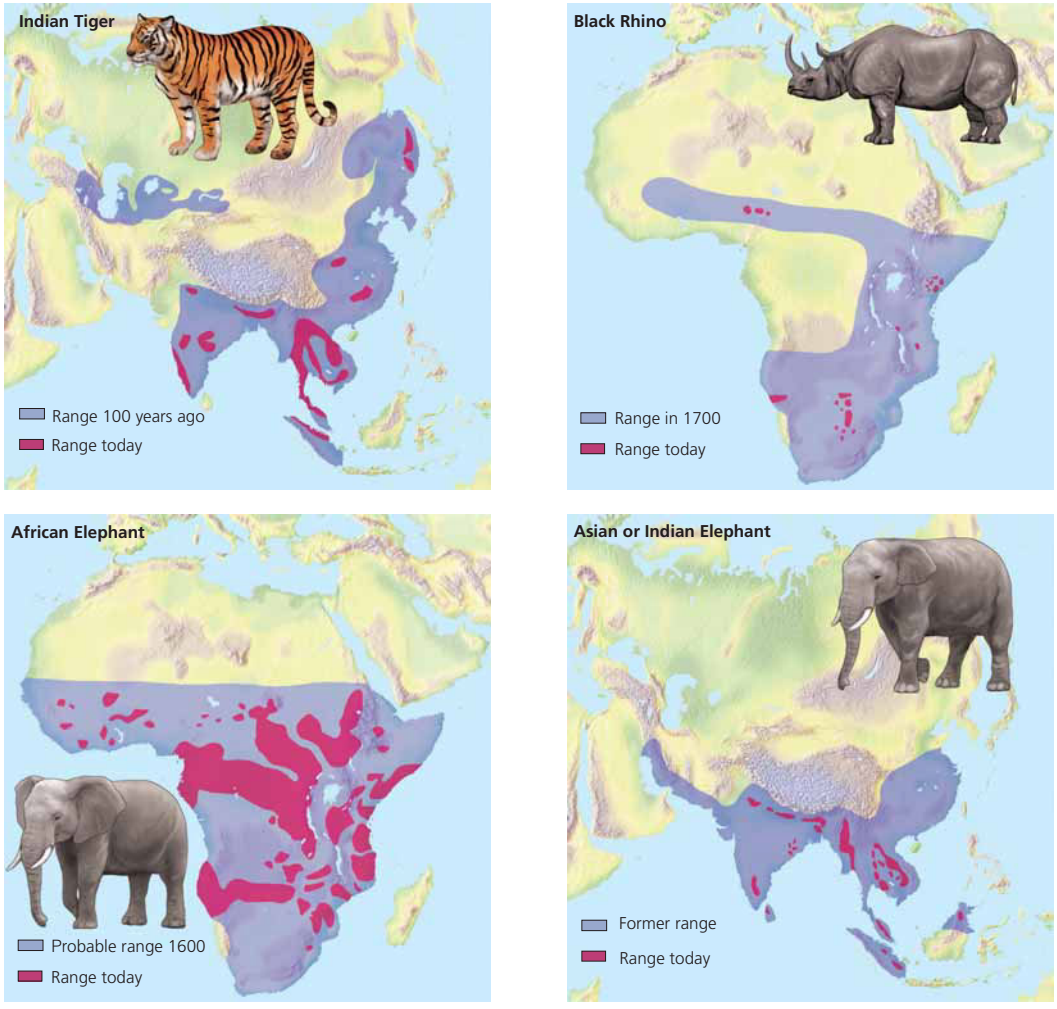


Figure 9-10 Underlying and direct causes of depletion and premature extinction of wild species (**Concept 9-3**). The major direct causes of wildlife depletion and premature extinction are habitat loss, degradation, and fragmentation. This is followed by the deliberate or accidental introduction of harmful invasive (nonnative) species into ecosystems. **Question:** What are two direct causes that are related to each of the underlying causes?



CENGAGENOW™ **Active Figure 9-11 Natural capital degradation:** reductions in the ranges of four wildlife species, mostly as the result of habitat loss and hunting. What will happen to these and millions of other species when the world's human population doubles and per capita resource consumption rises sharply in the next few decades? *See an animation based on this figure at* CengageNOW. **Question:** Would you support expanding these ranges even though this would reduce the land available for people to grow food and live on? Explain. (Data from International Union for the Conservation of Nature and World Wildlife Fund)

contiguous area of habitat is reduced in area and divided into smaller, more scattered, and isolated patches, or habitat islands. This process can decrease tree populations in forests (Science Focus, at right), block migration routes, and divide populations of a species into smaller and more isolated groups that are more vulnerable to predators, competitor species, disease, and catastrophic events such as storms and fires. Also, it creates barriers that limit the abilities of some species to disperse and colonize new areas, to get enough to eat, and to find mates. Migrating species also face dangers from fences, farms, paved areas, skyscrapers, and cell phone towers.

Certain types of species are especially vulnerable to local and regional extinction because of habitat fragmentation. They include species that are rare, species that need to roam unhindered over large areas, and species that cannot rebuild their populations because of a low reproductive capacity. Species with specialized niches and species that are sought by people for furs, food, medicines, or other uses are also especially threatened by habitat fragmentation.

Scientists use the theory of island biogeography (Science Focus, p. 90) to help them understand the effects of fragmentation on species extinction and to develop ways to help prevent such extinction.

SCIENCE FOCUS

Studying the Effects of Forest Fragmentation on Old-Growth Trees

Tropical rain forests typically consist of large numbers of different tree species with only a few members of each species in an area. Thus, most of the old-growth tree species in an area are rare and vulnerable to local or regional extinction when the forest is disturbed.

Tropical biologist Bill Laurance and his colleagues have been studying the nature of topical rain forests and how they are affected by human activities for over 25 years. One of his research interests is the effect of increasing fragmentation of tropical rain forests as people establish more roads, crop plantations, settlements, and cattle grazing areas.

The edges of forest fragments are often invaded by sun-loving species such as vines, which can gradually take over and cause the loss of a fragment's rare old-growth trees. Laurance is trying to determine how large the undisturbed inner core of a fragment must be to afford protection to its rare old-growth tree species.

His research team studies this by looking designated plots near the edge of a forest fragment and in the fragment's interior. In this example of muddy-boots ecology, they identify the tree species present in each plot. Then they measure the height and diameter of each tree to calculate its biomass and thus the total biomass of the trees in each plot. Such measurements are repeated every two years for two decades or more to determine changes in the species composition of the study plots.

Such painstaking research reveals that within 100 meters (330 feet) of the edge of a forest fragment, typically up to 36% of the biomass of old-growth trees is lost within 10-17 years after fragmentation. Plots in a fragment's interior show little loss of their tree biomass. Scientists can use such data to estimate how large a fragment must be in order to prevent the loss of rare trees within its protected core habitat. For more details on this research see *The Habitable Planet,* Video 9, at **www.learner.org/resources/series209.html**.

Critical Thinking

What are two ways to reduce the fragmentation of tropical rain forests?

CENGAGENOW™ See how serious the habitat fragmentation problem is for elephants, tigers, and rhinos at CengageNOW.

■ **CASE STUDY**

A Disturbing Message from the Birds

Approximately 70% of the world's nearly 10,000 known bird species are declining in numbers, and roughly one of every eight (12%) of these bird species is threatened with extinction, mostly because of habitat loss, degradation, and fragmentation. About three-fourths of the threatened bird species live in forests, many of which are being cleared at a rapid rate, especially in the tropical areas in Asia and Latin America (Figure 9-12).

Some 40% of Indonesia's moist, tropical forests, particularly in Borneo and Sumatra, has been cleared for lumber and palm plantations. The harvested palm oil is used as biofuel, mostly in European nations. As a result, 75% of the bird species in Sumatra's lowland forests are on the verge of extinction.

In Brazil, 115 bird species are threatened, mostly because of the burning and clearing of Amazon forests for farms and ranches. Other threats to Brazil's bird species are the loss of 93% of Brazil's Atlantic coastal rain forest and, most recently, the clearing of the country's savannah-like *cerrado* area to establish soybean plantations.

A 2007 joint study by the National Audubon Society and the American Bird Conservancy found that 30% of

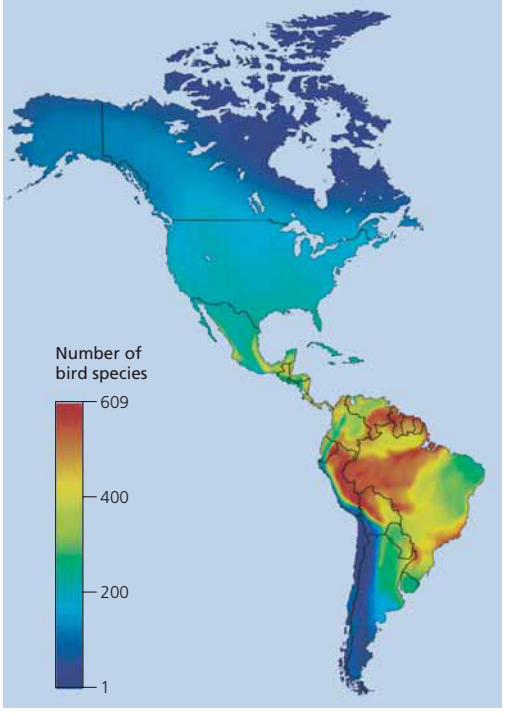


Figure 9-12 Distribution of bird species in North America and Latin America. **Question:** Why do you think more bird species are found in Latin America than in North America? (Data from The Nature Conservancy, Conservation International, World Wildlife Fund, and Environment Canada).

all North American bird species (25% of those living in the United States) and 70% of those living in grasslands are declining in numbers or are at risk of disappearing. A 2007 study by the American Bird Conservancy found that Hawaii's forests are the most threatened bird habitat. The government lists 30 of 71 remaining bird species in the Hawaiian Islands as endangered or threatened. Three other seriously threatened U.S. bird habitats are stream watersheds in the Southwest, tallgrass prairies in the Midwest, and beaches and marsh areas along the country's coastlines.

The numbers and distribution of North American bird species that can prosper around humans, such as robins, blackbirds, and starlings, have increased over the last 35 years. But populations of many forest songbirds have declined sharply. The greatest decline has occurred among long-distance migrant species such as tanagers, orioles, thrushes, vireos, and warblers that nest deep in North American woods in the summer and spend their winters in Central or South America or the Caribbean Islands. Figure 9-13 shows the 10 most threatened U.S. songbird species.

The primary culprit for these declines appears to be habitat loss and fragmentation of the birds' breeding habitats. In North America, woodlands are being cleared and broken up by roads and developments. In Central and South America, tropical forest habitats, mangroves, and wetland forests are suffering the same fate.

After habitat loss, the intentional or accidental introduction of nonnative species such as bird-eating cats, rats, snakes, and mongooses is the second greatest danger, affecting about 28% of the world's threatened birds. Fifty-two of the world's 388 parrot species (Figure 9-9) are threatened by a combination of habitat loss and capture for the pet trade (often illegal), especially in Europe and the United States.

At least 23 species of seabirds face extinction. Many seabirds drown after becoming hooked on one of the many baited lines put out by fishing boats. And populations of 40% of the world's water birds are in decline because of the global loss of wetlands.

when they collide with power lines, communications towers, and skyscrapers that have been erected in the middle of their migration routes. While U.S. hunters kill about 121 million birds a year, as many as 1 billion birds in the United States die each year when they fly into glass windows, especially those in tall city buildings that are lit up at night—the number one cause of U.S. bird mortality. Other threats to birds are oil spills, exposure to pesticides, herbicides that destroy their habi-

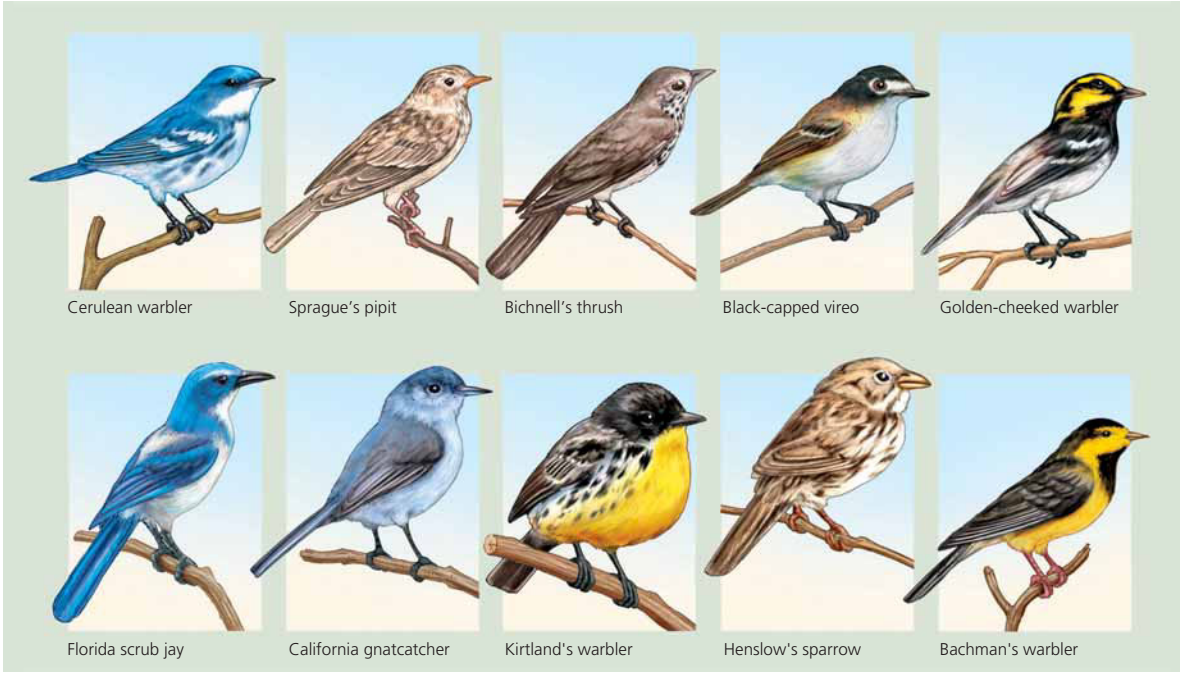


Figure 9-13 The 10 most threatened species of U.S. songbirds. Most of these species are vulnerable because of habitat loss and fragmentation from human activities. An estimated 12% of the world's known bird species may face premature extinction due mostly to human activities during this century. (Data from National Audubon Society)

SCIENCE FOCUS

Vultures, Wild Dogs, and Rabies: Some Unexpected Scientific Connections

In 2004, the World Conservation Union placed three species of vultures found in India and South Asia on the critically endangered list. During the early 1990s, there were more than 40 million of these carcass-eating vultures. But within a few years their populations had fallen by more than 97%.

This is an interesting scientific mystery, but should anyone care if various vulture species disappear? The answer is yes.

Scientists were puzzled, but they eventually discovered that the vultures were being poisoned by *diclofenac.* This anti-inflammatory drug reduces pain in cows and in humans and is used to increase milk production in cows. But it causes kidney failure in vultures that feed on the carcasses of these cows.

As the vultures died off, huge numbers of cow carcasses, normally a source of food for the vultures, were consumed by wild dogs and rats whose populations the vultures helped control by reducing their food supply. As wild dog populations exploded due to a greatly increased food supply, the number of dogs with rabies also increased. This increased the risks to people bitten by rabid dogs. In 1997 alone, more than 30,000 people in India died of rabies—more than half the world's total number of rabies deaths that year.

Thus, protecting these vulture species from extinction can end up protecting millions of people from a life-threatening disease. Unraveling often unexpected ecological connections in nature is not only fascinating but also vital to our own lives and health.

Some who argue against protecting species and ecosystems from harmful human activities frame the issue as a choice between protecting people or wildlife. Conservation biologists reject this as a misleading conclusion. To them, the goal is to protect both wildlife and people because their fates and well-being are interconnected.

Critical Thinking

What would happen to your life and lifestyle if most of the world's vultures disappeared?

tats, and ingestion of toxic lead shotgun pellets, which fall into wetlands, and lead sinkers left by anglers.

The greatest new threat to birds is climate change. A 2006 review, done for the World Wildlife Fund (WWF), of more than 200 scientific articles found that climate change is causing declines of bird populations in every part of the world. And climate change is expected to increase sharply during this century.

Migratory, mountain, island, wetland, Antarctic, Arctic, and sea birds are especially at risk from climate change. The researchers have warned that protecting many current areas with high bird diversity will not help, because climate change will force many bird species to shift to unprotected zones. Island and mountain birds may simply have nowhere to go.

Conservation biologists view this decline of bird species with alarm. One reason is that birds are excellent *environmental indicators* because they live in every climate and biome, respond quickly to environmental changes in their habitats, and are relatively easy to track and count.

Furthermore, birds perform a number of important economic and ecological services in ecosystems throughout the world. They help control populations of rodents and insects (which decimate many tree species), remove dead animal carcasses (a food source for some birds), and spread plants throughout their habitats by helping with pollination and by consuming and excreting plant seeds.

Extinctions of birds that play key and specialized roles in pollination and seed dispersal, especially in tropical areas, may lead to extinctions of plants dependent on these ecological services. Then some specialized animals that feed on these plants may also become extinct. This cascade of extinctions, in turn, can affect our own food supplies and well-being. Protecting birds and their habitats is not only a conservation issue. It is an important issue for human health as well (Science Focus, above).

Biodiversity scientists urge us to listen more carefully to what birds are telling us about the state of the environment, for the birds' sake, as well as for ours.

THINKING ABOUT
Bird Extinctions

How does your lifestyle directly or indirectly contribute to the premature extinction of some bird species? What are three things that you think should be done to reduce the premature extinction of birds?

RESEARCH FRONTIER

Learning more about why birds are declining, what it implies for the biosphere, and what can be done about it. See **academic.cengage.com/biology/miller**.

Some Deliberately Introduced Species Can Disrupt Ecosystems

After habitat loss and degradation, the biggest cause of premature animal and plant extinctions is the deliberate or accidental introduction of harmful invasive species into ecosystems (**Concept 9-3**).

Most species introductions are beneficial to us, although they often displace native species. We depend heavily on introduced species for ecosystem services, food, shelter, medicine, and aesthetic enjoyment.

According to a 2000 study by ecologist David Pimentel, introduced species such as corn, wheat, rice, and other food crops, and cattle, poultry, and other livestock provide more than 98% of the U.S. food supply. Similarly, nonnative tree species are grown in about 85% of the world's tree plantations. Some deliberately introduced species have also helped to control pests.

The problem is that some introduced species have no natural predators, competitors, parasites, or pathogens to help control their numbers in their new habitats. Such nonnative species can reduce or wipe out populations of many native species, trigger ecological disruptions, cause human health problems, and lead to economic losses.

In 1988, for example, a giant African land snail was imported into Brazil as a cheap substitute for conventional escargot (snails) used as a source of food. It grows to the size of a human fist and weighs 1 kilogram (2.2 pounds) or more. When export prices for escargot fell, breeders dumped the snails into the wilds. Now it has spread to 23 of Brazil's states and devours everything from lettuce to mouse droppings. It also can carry rat lungworm, a parasite that burrows into the human brain and causes meningitis, and another parasite that can rupture the intestines. Authorities eventually banned the snail, but it was too late. So far, the snail has been unstoppable.

Figure 9-14 shows some of the estimated 7,100 harmful invasive species that, after being deliberately or accidentally introduced into the United States, have caused ecological and economic harm. Nonnative species threaten almost half of the roughly 1,300 endangered and threatened species in the United States and 95% of those in the state of Hawaii, according to the U.S. Fish and Wildlife Service. According to biologist Thomas Lovejoy, harmful invader species cost the U.S. public an average of $261,000 per minute! The situation in China is much worse. Biologist David Pimentel estimates that, globally, damage to watersheds, soils, and wildlife by bioinvaders may be costing as much $44,400 per second. And the damages are rising rapidly.

Some deliberately introduced species are plants such as kudzu (Case Study, at right). Deliberately introduced animal species have also caused ecological and economic damage. Consider the estimated 1 million European wild (feral) boars (Figure 9-14) found in parts of Florida and other U.S. states. They compete for food with endangered animals, root up farm fields, and cause traffic accidents. Game and wildlife officials have failed to control their numbers through hunting and trapping and say there is no way to stop them. Another example is the estimated 30 million feral cats and 41 million outdoor pet cats found in the United States. Most were introduced to the environment when they were abandoned by their owners and left to breed in the wild; they kill about 568 million birds per year. Because of pet overpopulation and abandonment, pet shelters in the United States are forced to kill over 14 million cats and dogs a year. Shelter officials urge owners to spay or neuter their cats and keep them indoors.

CASE STUDY

The Kudzu Vine

An example of a deliberately introduced plant species is the *kudzu* ("CUD-zoo") *vine,* which, in the 1930s, was imported from Japan and planted in the southeastern United States in an attempt to control soil erosion. Kudzu does control erosion. But it is so prolific and difficult to kill that it engulfs hillsides, gardens, trees, abandoned houses and cars, stream banks, patches of forest, and anything else in its path (Figure 9-15, p. 200).

This plant, which is sometimes called "the vine that ate the South," has spread throughout much of the southeastern United States. It could spread as far north as the Great Lakes by 2040 if climate change caused by global warming occurs as projected.

Kudzu is considered a menace in the United States but Asians use a powdered kudzu starch in beverages, gourmet confections, and herbal remedies for a range of diseases. A Japanese firm has built a large kudzu farm and processing plant in the U.S. state of Alabama and ships the extracted starch to Japan. And almost every part of the kudzu plant is edible. Its deep-fried leaves are delicious and contain high levels of vitamins A and C. Stuffed kudzu leaves, anyone?

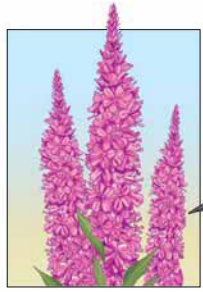
Although kudzu can engulf and kill trees, it might eventually save some trees from loggers. Researchers at the Georgia Institute of Technology indicate that it could be used in place of trees as a source of fiber for making paper. And a preliminary 2005 study indicated that kudzu powder could be used to reduce alcoholism and binge drinking. Ingesting small amounts of the powder can lessen one's desire for alcohol.

Some Accidentally Introduced Species Can Also Disrupt Ecosystems

Welcome to one of the downsides of global trade, travel, and tourism. Many unwanted nonnative invaders arrive from other continents as stowaways on aircraft, in the ballast water of tankers and cargo ships, and as hitchhikers on imported products such as wooden packing crates. Cars and trucks can also spread the seeds of nonnative plant species embedded in their tire treads. Many tourists return home with living plants that can multiply and become invasive. These plants might also harbor insects that can escape, multiply rapidly, and threaten crops.

In the 1930s, the extremely aggressive Argentina fire ant (Figures 9-14 and 9-16, p. 200) was introduced accidentally into the United States in Mobile, Alabama.

Deliberately Introduced Species

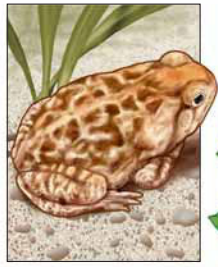

Purple loosestrife

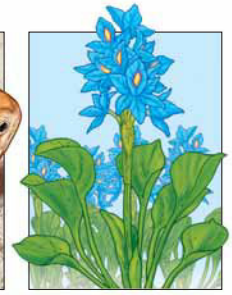

European starling


African honeybee ("Killer bee")


Nutria


Salt cedar (Tamarisk)


Marine toad (Giant toad)

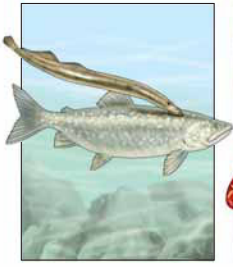

Water hyacinth


Japanese beetle


Hydrilla

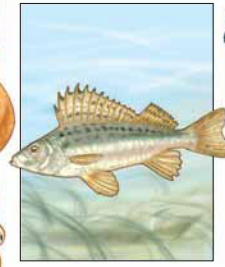

European wild boar (Feral pig)

Accidentally Introduced Species


Sea lamprey (attached to lake trout)


Argentina fire ant


Brown tree snake

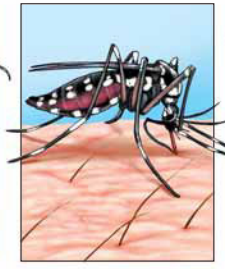

Eurasian ruffe


Common pigeon (Rock dove)


Formosan termite


Zebra mussel


Asian long-horned beetle


Asian tiger mosquito

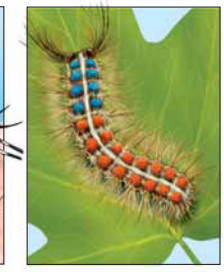

Gypsy moth larvae

Figure 9-14 Some of the more than 7,100 harmful invasive (nonnative) species that have been deliberately or accidentally introduced into the United States.

Image not available due to copyright restrictions

The ants may have arrived on shiploads of lumber or coffee imported from South America. Without natural predators, fire ants have spread rapidly by land and water (they can float) throughout the South, from Texas to Florida and as far north as Tennessee and Virginia.

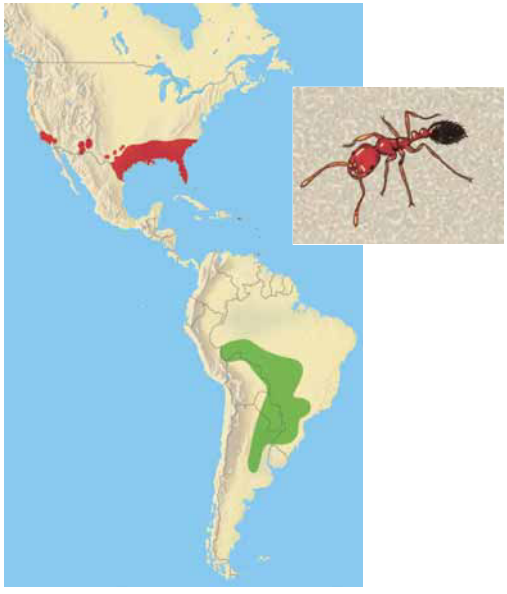


Figure 9-16 The *Argentina fire ant,* introduced accidentally into Mobile, Alabama, in the 1930s from South America (green area), has spread over much of the southern United States (red area). This invader is also found in Puerto Rico, New Mexico, and California. **Question:** How might this accidental introduction of fire ants have been prevented? (Data from S. D. Porter, Agricultural Research Service, U.S. Department of Agriculture)

When these ants invade an area, they can wipe out as much as 90% of native ant populations. Mounds containing fire ant colonies cover many farm fields and invade people's yards. Walk on one of these mounds, and as many as 100,000 ants may swarm out of their nest to attack you with painful and burning stings. They have killed deer fawns, birds, livestock, pets, and at least 80 people who were allergic to their venom. In the United States, they also do an estimated $68,000 of economic damage per hour to crops and phone and power lines.

Widespread pesticide spraying in the 1950s and 1960s temporarily reduced fire ant populations. But this chemical warfare actually hastened the advance of the rapidly multiplying fire ants by reducing populations of many native ant species. Even worse, it promoted development of genetic resistance to pesticides in the fire ants through natural selection (**Concept 4-2B**, p. 80). In other words, we helped wipe out their competitors and made them more genetically resistant to pesticides.

CONCEPT LINK

In the Everglades in the U.S. state of Florida, the population of the huge *Burmese python* snake is increasing. This native of Southeast Asia was imported as a pet, and many ended up being dumped in the Everglades by people who learned that, when they get larger, pythons do not make good pets. They can live 25 years, reach 6 meters (20 feet) in length, weigh more than 90 kilograms (200 pounds), and have the girth of a telephone pole. They have razor-sharp teeth and can catch, squeeze to death, and swallow whole practically anything that moves and is warm-blooded, including raccoons, a variety of birds, and full-grown deer. They are also known to have survived alligator attacks. They are slowly spreading to other areas and, by 2100, could be found in most of the southern half of the continental United States.

Prevention Is the Best Way to Reduce Threats from Invasive Species

Once a harmful nonnative species becomes established in an ecosystem, its removal is almost impossible—somewhat like trying to get smoke back into a chimney. Clearly, the best way to limit the harmful impacts of nonnative species is to prevent them from being introduced and becoming established.

Scientists suggest several ways to do this:

- Fund a massive research program to identify the major characteristics of successful invader species and the types of ecosystems that are vulnerable to invaders (Figure 9-17).
- Greatly increase ground surveys and satellite observations to detect and monitor species invasions and develop better models for predicting how they will spread.
- Step up inspection of imported goods and goods carried by travelers that are likely to contain invader species.
- Identify major harmful invader species and establish international treaties banning their transfer from one country to another, as is now done for endangered species.
- Require cargo ships to discharge their ballast water and replace it with saltwater at sea before entering ports, or require them to sterilize such water or pump nitrogen into the water to displace dissolved oxygen and kill most invader organisms.
- Increase research to find and introduce natural predators, parasites, bacteria, and viruses to control populations of established invaders.

Characteristics of Successful Invader Species

- High reproductive rate, short generation time (r-selected species)
- Pioneer species
- Long lived
- High dispersal rate
- Generalists
- High genetic variability

Characteristics of Ecosystems Vulnerable to Invader Species

- Climate similar to habitat of invader
- Absence of predators on invading species
- Early successional systems
- Low diversity of native species
- Absence of fire
- Disturbed by human activities

Figure 9-17 Some general characteristics of successful invader species and ecosystems vulnerable to invading species. **Question:** Which, if any, of the characteristics on the right-hand side could humans influence?

WHAT CAN YOU DO?

Controlling Invasive Species

- Do not capture or buy wild plants and animals
- Do not remove wild plants from their natural areas
- Do not dump the contents of an aquarium into waterways, wetlands, or storm drains
- When camping, use wood found near your camp site instead of bringing firewood from somewhere else
- Do not dump unused bait into any waterways
- After dogs visit woods or the water, brush them before taking them home
- After each use, clean your mountain bike, canoe, boat, hiking boots, and other gear before heading for home

Figure 9-18 **Individuals Matter:** ways to prevent or slow the spread of harmful invasive species. **Questions:** Which two of these actions do you think are the most important? Why? Which of these actions do you plan to take?

RESEARCH FRONTIER

Learning more about invasive species, why they thrive, and how to control them. See **academic.cengage.com/biology/miller**.

Figure 9-18 shows some of the things you can do to help prevent or slow the spread of these harmful invaders.

Population Growth, Overconsumption, Pollution, and Climate Change Can Cause Species Extinctions

Human population growth and excessive and wasteful consumption of resources have greatly expanded the human ecological footprint (Figure 1-10, p. 15; and Figure 3, pp. S24–S25, in Supplement 4), which has eliminated vast areas of wildlife habitat (Figure 9-11). Acting together, these factors have caused premature extinction of many species (**Concept 9-3**). (See *The Habitable Planet,* Video 13, at **www.learner.org/resources/series209.html**).

Pollution also threatens some species with extinction (**Concept 9-3**), as has been shown by the unintended effects of certain pesticides. According to the U.S. Fish and Wildlife Service, each year pesticides kill about one-fifth of the beneficial honeybee colonies in United States (Case Study, p. 202), more than 67 million birds, and 6–14 million fish. They also threaten about one-fifth of the country's endangered and threatened species.

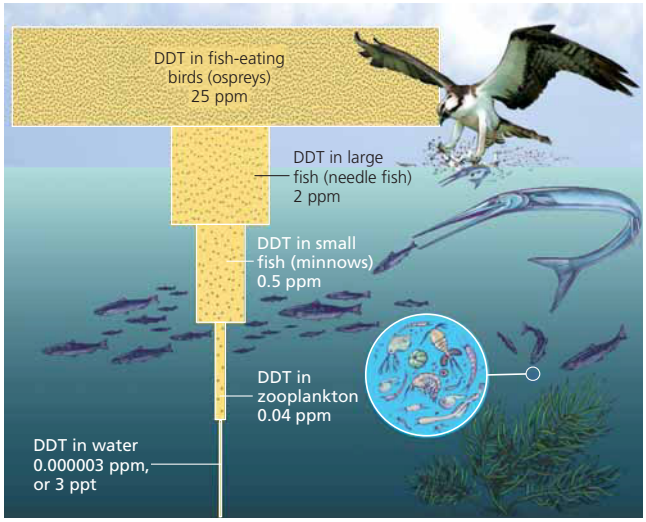


Figure 9-19 *Bioaccumulation* and *biomagnification.* DDT is a fat-soluble chemical that can accumulate in the fatty tissues of animals. In a food chain or web, the accumulated DDT can be biologically magnified in the bodies of animals at each higher trophic level. The concentration of DDT in the fatty tissues of organisms was biomagnified about 10 million times in this food chain in an estuary near Long Island Sound in the U.S. state of New York. If each phytoplankton organism takes up from the water and retains one unit of DDT, a small fish eating thousands of zooplankton (which feed on the phytoplankton) will store thousands of units of DDT in its fatty tissue. Each large fish that eats 10 of the smaller fish will ingest and store tens of thousands of units, and each bird (or human) that eats several large fish will ingest hundreds of thousands of units. Dots represent DDT. **Question:** How does this story demonstrate the value of pollution prevention?

During the 1950s and 1960s, populations of fish-eating birds such as ospreys, brown pelicans (see Photo 1 in the Detailed Contents), and bald eagles plummeted. A chemical derived from the pesticide DDT, when biologically magnified in food webs (Figure 9-19), made the birds' eggshells so fragile that they could not reproduce successfully. Also hard hit were such predatory birds as the prairie falcon, sparrow hawk, and peregrine falcon, which help to control rabbits, ground squirrels, and other crop eaters.

Since the U.S. ban on DDT in 1972, most of these species have made a comeback. For example, after eliminating DDT and after crackdowns on hunting and habitat destruction, the American bald eagle has rebounded from only 417 breeding pairs in the lower 48 states in 1963 to almost 10,000 breeding pairs in 2007. This was enough to have it removed from the endangered species list. The comeback of this species from the brink of extinction is one of the greatest wildlife protection successes in U.S. history.

A 2004 study by Conservation International predicted that climate change caused mostly by global warming (Science Focus, p. 33) could drive more than a quarter of all land animals and plants to extinction by the end of this century. Some scientific studies indicate that polar bears (Case Study, p. 203) and 10 of the world's 17 penguin species are already threatened because of higher temperatures and melting sea ice in their polar habitats.

■ CASE STUDY

Where Have All the Honeybees Gone?

Three-quarters of all flowering plants in North America—including most fruit and vegetable crops—rely on pollinators such as bees, bats (Science Focus, p. 192), butterflies, and hummingbirds for fertilization.

According to a 2006 report by the U.S. National Academy of Sciences (NAS), populations of such vital pollinators are declining across North America, and honeybee populations have been in increasing trouble for over 2 decades. The report warns that continued decreases in wild populations of such pollinators could disrupt food production and ecosystems.

The report includes a specific warning on the decline of the honeybee, which pollinates more than 110 commercially grown crops that are vital to U.S. agriculture, including up to one-third of U.S. fruit and vegetable crops. Globally, about one-third of the human diet comes from insect-pollinated plants, and the honeybee is responsible for 80% of that pollination, according to the U.S. Department of Agriculture. Adult honeybees live on honey that they make from nectar they collect from flowering plants, and they feed their young with protein-rich pollen.

Honeybees are big business. In the United States, honeybee colonies are managed by beekeepers who rent the bees out for their pollination services, especially for major crops such as almonds, apples, and blueberries. By 1994, such colonies had replaced an estimated 98% of the wild, free-range honeybees in the United States.

According to the NAS report, there has been a 30% drop in U.S. honeybee populations since the 1980s. Causes include pesticide exposure (the wax in beehives absorbs these and other airborne toxins), attacks by parasitic mites that can wipe out a colony in hours, and invasion by African honeybees (killer bees, p. 93).

Since 2006, a growing number of bee colonies in 27 states have suffered what researchers call "bee colony collapse disorder," or what French scientists call "mad bee disease," in which the worker bees in a colony vanish without a trace. When beekeepers inspect what were once healthy and strong colonies, they find all of the adult worker bees gone and an abandoned queen bee.

More than a quarter of the country's 2.4 million honeybee colonies (each with 30,000 to 100,000 individual bees) have been lost. Nobody knows where the missing bees went or what is causing them to leave the hives. Possible causes include parasites, fungi, bacteria,

and pesticides. Scientists also suspect a virus that paralyzes bees, which may have come from Israel or from bees imported from Australia to help replace declining U.S. honeybee populations. Another problem is poor nutrition and stress caused when colonies of bees are fed an artificial diet while being trucked around the country and rented out for pollination.

Scientists are also finding sharp declines in some species of bumblebees found in the United States. These bees are responsible for pollinating an estimated 15% of the crops grown in the United States, especially those that are raised in greenhouses, such as tomatoes, peppers, and strawberries. Bumblebees collect pollen and nectar to feed their young, but make very little honey.

Declining bee populations have also been reported in Brazil, Taiwan, Guatemala, and parts of Europe. China, where some argue that pesticides are overused, gives us a glimpse of a future without honeybees. Apple orchards in China are now largely hand-fertilized by humans in the absence of bees. Some scientists warn that if it continues and grows, *bee colony collapse disorder* could lead to *agricultural collapse disorder* in parts of the world.

THINKING ABOUT

Bees

What difference would it make to your lifestyle if most of the honeybees or bumblebees disappeared? What two things would you do to help reduce the loss of honeybees?

■ CASE STUDY

Polar Bears and Global Warming

The world's 20,000–25,000 polar bears are found in 19 populations distributed across the frozen Arctic. About 60% of them are in Canada, and the rest are found in arctic areas in Denmark, Norway, Russia, and the U.S. state of Alaska.

Throughout the winter, the bears hunt for seals on floating sea ice (Figure 9-20), which expands southward each winter and contracts as the temperature rises each summer. Normally the bears swim from one patch of sea ice to another to hunt and eat seals during winter as their body fat accumulates. In the summer and fall as sea ice breaks up, the animals fast and live off their body fat for several months until hunting resumes when the ice again expands.

Evidence shows that the Arctic is warming twice as fast as the rest of the world and that the average annual area of floating summer sea ice in the Arctic is declining and is breaking up earlier each year. Scientists project that summer sea ice could be gone by 2030 and perhaps as soon as 2012.

This means that polar bears have less time to feed and to store the fat they need in order to survive their summer and fall months of fasting. As a result, they must fast longer, which weakens them. As females become weaker, their ability to reproduce and keep their young cubs alive declines. And as bears grow hungrier, they are more likely to go to human settlements looking for food. The resulting increase in bear sightings gives people the false impression that their populations are increasing.

Polar bears are strong swimmers, but ice shrinkage has forced them to swim longer distances to find enough food and to spend more time during winter hunting on land where prey is nearly impossible to find. Several studies link global warming and diminished sea ice to polar bears drowning or starving while in search of prey and, in some cases, to cannibalism among the bears.

According to a 2006 study by the IUCN–World Conservation Union, the world's total polar bear population is likely to decline by 30–35% by 2050, and by the end of this century, the bears may be found only in zoos.

Another threat to the bears in some areas is the buildup of toxic PCBs, DDT (Figure 9-19), and other pesticides in their fatty tissue, which can adversely affect their development, behavior, and reproduction. And in 2007, the U.S. Fish and Wildlife Service estimated that Russian poachers are killing 100–250 polar bears a year.

In 2007, the IUCN listed polar bears as threatened in their annual red list of endangered species, and in 2008, the U.S. government listed the polar bear as threatened under the Endangered Species Act.

Figure 9-20 Polar bear with seal prey on floating ice in Svalbard, Norway. Polar bears in the Arctic are likely to become extinct sometime during this century because global warming is melting the floating sea ice on which they hunt seals.

THINKING ABOUT
Polar Bears

What difference would it make if all of the world's polar bears disappeared? List two things you would do to help protect the world's remaining polar bears from premature extinction.

Illegal Killing, Capturing, and Selling of Wild Species Threatens Biodiversity

Some protected species are illegally killed for their valuable parts or are sold live to collectors (**Concept 9-3**). Such *poaching* endangers many larger animals and some rare plants. Globally, this illegal trade in wildlife earns smugglers at least $10 billion a year—an average of $19,000 a minute. Organized crime has moved into illegal wildlife smuggling because of the huge profits involved—surpassed only by the illegal international trade in drugs and weapons. Rapidly growing wildlife smuggling is a high-profit, low-risk business because few of the smugglers are caught or punished. At least two-thirds of all live animals smuggled around the world die in transit.

To poachers, a live mountain gorilla is worth $150,000, a giant panda pelt $100,000, a chimpanzee $50,000, an Imperial Amazon macaw $30,000, and a Komodo dragon reptile from Indonesia $30,000. A poached rhinoceros horn (Figure 9-21) can be worth as much as $55,500 per kilogram ($25,000 per pound). It is used to make dagger handles in the Middle East and as a fever reducer and alleged aphrodisiac in China and other parts of Asia.

According to a 2005 study by the International Fund for Animal Welfare, the Internet has become a key market for the illegal global trade in thousands of live threatened and endangered animals and products made from such animals. For example, U.S. websites offered live chimpanzees dressed as dolls for $60,000–65,000 each and a 2-year-old highly endangered Siberian tiger for $70,000.

An important way to combat the illegal trade in these species is through research and education. Some people are dedicating their time and energy to this problem. For example, scientist Jane Goodall has devoted her life to understanding and protecting chimpanzees (Individuals Matter, at right).

In 1900, an estimated 100,000 tigers roamed free in the world. Despite international protection, only about 3,500 tigers remain in the wild, on an ever shrinking range (Figure 9-11, top left), according to a 2006 study by the World Conservation Union. Between 1900 and 2007, the estimated number of tigers in India plunged from 40,000 to about 1,400. In 2007, Eric Dinerstein and his colleagues estimated that tigers have 41% less habitat than they had in 1997, mostly because of deforestation and forest fragmentation, and now live in just 7% of their historic range around the world. Today all five tiger subspecies are endangered in the wild, although at least 11,000 captive tigers of mixed ancestry exist behind bars.

Martin Harvey/Peter Arnold, Inc

Figure 9-21 White rhinoceros killed by a poacher for its horn in South Africa. **Question:** What would you say if you could talk to the poacher of this animal?

Tigers are also threatened because they are killed for their coats and body parts. The Bengal or Indian tiger is at risk because a coat made from its fur can sell for as much as $100,000 in Tokyo. Wealthy collectors have paid $10,000 to $20,000 for a Bengal tiger rug. With the body parts of a single tiger worth as much as $25,000, and because few of the poachers are caught or punished, it is not surprising that illegal hunting has skyrocketed. According to a 2006 study by tiger experts, without emergency action to curtail poaching and preserve their habitat, few if any tigers may be left in the wild within 20 years.

THINKING ABOUT
Tigers

What difference would it make if all the world's tigers disappeared? What two things would you do to help protect the world's remaining tigers from premature extinction?

The global legal and illegal trade in wild species for use as pets is also a huge and very profitable business. Many owners of wild pets do not know that, for every live animal captured and sold in the pet market, an es-

timated 50 others are killed or die in transit. Most are also unaware that some imported exotic animals can carry dangerous infectious diseases.

About 25 million U.S. households have exotic birds as pets, 85% of them imported. More than 60 bird species, mostly parrots, (Figure 9-9), are endangered or threatened because of this wild bird trade. Ironically, keeping birds as pets can also be dangerous for people. A 1992 study suggested that keeping a pet bird indoors for more than 10 years doubles a person's chances of getting lung cancer from inhaling tiny particles of bird dander.

Other wild species whose populations are depleted because of the pet trade include amphibians, reptiles, mammals, and tropical fishes (taken mostly from the coral reefs of Indonesia and the Philippines). Divers catch tropical fish by using plastic squeeze bottles of poisonous cyanide to stun them. For each fish caught alive, many more die. In addition, the cyanide solution kills the coral animals that create the reef.

Some exotic plants, especially orchids and cacti, are endangered because they are gathered (often illegally) and sold to collectors to decorate houses, offices, and landscapes. A collector may pay $5,000 for a single rare orchid. A mature crested saguaro cactus can earn cactus rustlers as much as $15,000.

THINKING ABOUT
Collecting Wild Species

Some people believe it is unethical to collect wild animals and plants for display and personal pleasure. They believe we should leave most exotic wild species in the wild. Explain why you agree or disagree with this view.

As commercially valuable species become endangered, their black market demand soars. This positive feedback loop increases their chances of premature extinction from poaching. Most poachers are not caught and the money they can make far outweighs the small risk of being caught, fined, or imprisoned.

On the other hand, species also hold great value by surviving in the wild. According to the U.S. Fish and Wildlife Service, collectors of exotic birds may pay $10,000 for a threatened hyacinth macaw smuggled out of Brazil. But during its lifetime, a single macaw left in the wild might yield as much as $165,000 in tourist revenues.

In Thailand, biologist Pilai Poonswad decided to do something about poachers taking Great Indian hornbills—large, beautiful, and rare birds—from a rain forest. She visited the poachers in their villages and showed them why the birds are worth more alive than dead. Today, some former poachers earn money by taking ecotourists into the forest to see these magnificent birds. Because of their vested financial interest in preserving the hornbills, they now help to protect the birds from poachers. Individuals matter.

INDIVIDUALS MATTER

Jane Goodall

Primatologist and anthropologist Jane Goodall (Figure 9-A) spent 45 years studying chimpanzee social and family life in Gombe National Park in the African country of Tanzania. One of her major scientific contributions was the discovery that chimpanzees have tool-making skills. She observed that some chimpanzees modified twigs or blades of grass and then poked them into termite mounds. When the termites latched onto these primitive tools, the chimpanzees would pull them out and eat the termites.

M. Gunther/BIOS/Peter Arnold, Inc.

Figure 9-A Jane Goodall with a young chimpanzee living in Tanzania's Gombe National Park.

In 1977, she established the Jane Goodall Institute, which supports the research at Gombe National Park and, with 19 offices around the world, works to protect chimpanzees and their habitats. Dr. Goodall spends nearly 300 days a year traveling and educating people throughout the world about chimpanzees and the need to protect the environment.

Goodall is also president of Advocates for Animals, an animal rights organization based in Edinburgh, Scotland, that campaigns against the use of animals for medical research, zoos, farming, and sport hunting. She has received many awards and prizes for her scientific and conservation contributions. She has also written 23 books for adults and children and has produced 14 films about the lives and importance of chimpanzees.

Rising Demand for Bush Meat Threatens Some African Species

Indigenous people in much of West and Central Africa have sustainably hunted wildlife for *bush meat,* a source of food, for centuries. But in the last two decades bush meat hunting in some areas has skyrocketed as local people try to provide food for rapidly growing populations or seek to make a living by supplying restaurants with exotic meat (Figure 9-22, p. 206). Logging roads have enabled miners, ranchers, and settlers to move into once inaccessible forests, which has made it easier to hunt animals for bush meat. And a 2004 study showed that people living in coastal areas of West Africa have increased bush meat hunting because local fish harvests have declined due to overfishing by heavily subsidized European Union fishing fleets.

So what is the big deal? After all, people have to eat. For most of our existence, humans have survived by hunting and gathering wild species.

Jacques Fretey/Peter Arnold, Inc.

Figure 9-22 *Bush meat,* such as this severed head of a lowland gorilla in the Congo, is consumed as a source of protein by local people in parts of West Africa and sold in the national and international marketplace. You can find bush meat on the menu in Cameroon and the Congo in West Africa as well as in Paris, London, Toronto, New York, and Washington, D.C. It is often supplied by poaching. Wealthy patrons of some restaurants regard gorilla meat as a source of status and power. **Question:** How, if at all, is this different from killing a cow for food?

One problem today is that bush meat hunting has led to the local extinction of many wild animals in parts of West Africa and has driven one species—Miss Waldron's red colobus monkey—to complete extinction. It is also a factor in reducing gorilla, orangutan (Figure 9-7), chimpanzee, elephant, and hippopotamus populations. This practice also threatens forest carnivores, such as crowned eagles and leopards, by depleting their main prey species.

Some conservationists fear that within 1 or 2 decades, the Congo basin's rain forest—the world's second largest remaining tropical forest—will contain few large mammals, and most of Africa's great apes will be extinct. Another problem is that butchering and eating some forms of bush meat has helped to spread fatal diseases such as HIV/AIDS and the Ebola virus to humans.

The U.S. Agency for International Development is trying to reduce unsustainable hunting for bush meat in some areas by introducing alternative sources of food, such as fish farms. They are also showing villagers how to breed large rodents such as cane rats as a source of food.

THINKING ABOUT

The Passenger Pigeon and Humans

CORE CASE STUDY

Humans exterminated the passenger pigeon (Figure 9-1) within a single human lifetime because it was considered a pest and because of its economic value. Suppose a species superior to us arrived and began taking over the earth with the goal of using the planet more sustainably. The first thing they might do is to exterminate us. Do you think such an action would be justified? Explain.

9-4 How Can We Protect Wild Species from Extinction Resulting from Our Activities?

- **CONCEPT 9-4A** **We can use existing environmental laws and treaties and work to enact new laws designed to prevent premature species extinction and protect overall biodiversity.**
- **CONCEPT 9-4B** **We can help to prevent premature species extinction by creating and maintaining wildlife refuges, gene banks, botanical gardens, zoos, and aquariums.**
- **CONCEPT 9-4C** **According to the *precautionary principle,* we should take measures to prevent or reduce harm to the environment and to human health, even if some of the cause-and-effect relationships have not been fully established, scientifically.**

International Treaties Help to Protect Species

Several international treaties and conventions help to protect endangered and threatened wild species (**Concept 9-4A**). One of the most far reaching is the 1975 *Convention on International Trade in Endangered Species* (CITES). This treaty, now signed by 172 countries, bans hunting, capturing, and selling of threatened or endangered species. It lists some 900 species that cannot be commercially traded as live specimens or wildlife products because they are in danger of extinction. It also restricts international trade of roughly 5,000 species of animals and 28,000 plants species that are at risk of becoming threatened.

CITES has helped reduce international trade in many threatened animals, including elephants, crocodiles, cheetahs, and chimpanzees. But the effects of

this treaty are limited because enforcement varies from country to country, and convicted violators often pay only small fines. Also, member countries can exempt themselves from protecting any listed species, and much of the highly profitable illegal trade in wildlife and wildlife products goes on in countries that have not signed the treaty.

The *Convention on Biological Diversity* (CBD), ratified by 190 countries (but not by the United States), legally commits participating governments to reversing the global decline of biodiversity and to equitably sharing the benefits from use of the world's genetic resources. This includes efforts to prevent or control the spread of ecologically harmful invasive species.

This convention is a landmark in international law because it focuses on ecosystems rather than on individual species and it links biodiversity protection to issues such as the traditional rights of indigenous peoples. However, because some key countries including the United States have not ratified it, implementation has been slow. Also, the law contains no severe penalties or other enforcement mechanisms.

■ CASE STUDY

The U.S. Endangered Species Act

The *Endangered Species Act of 1973* (ESA; amended in 1982, 1985, and 1988) was designed to identify and protect endangered species in the United States and abroad (**Concept 9-4A**). This act is probably the most far-reaching environmental law ever adopted by any nation, which has made it controversial. Canada and a number of other countries have similar laws.

Under the ESA, the National Marine Fisheries Service (NMFS) is responsible for identifying and listing endangered and threatened ocean species, while the U.S. Fish and Wildlife Services (USFWS) is to identify and list all other endangered and threatened species. Any decision by either agency to add a species to, or remove one from, the list must be based on biological factors alone, without consideration of economic or political factors. However, economic factors can be used in deciding whether and how to protect endangered habitat and in developing recovery plans for listed species.

The ESA also forbids federal agencies (except the Defense Department) to carry out, fund, or authorize projects that would jeopardize an endangered or threatened species or destroy or modify its critical habitat. For offenses committed on private lands, fines as high as $100,000 and 1 year in prison can be imposed to ensure protection of the habitats of endangered species. This part of the act has been controversial because at least 90% of the listed species live totally or partially on private land. The ESA also makes it illegal for Americans to sell or buy any product made from an endangered or threatened species or to hunt, kill, collect, or injure such species in the United States.

Between 1973 and 2007, the number of U.S. species on the official endangered and threatened lists increased from 92 to about 1,350 species—55% of them plants and 45% animals. According to a 2000 study by The Nature Conservancy, one-third of the country's species are at risk of extinction, and 15% of all species are at high risk—far more than the roughly 1,350 species on the country's endangered species list. The study also found that many of the country's rarest and most imperiled species are concentrated in a few areas, called *hotspots*. To conservation biologists, protecting such areas should be a top priority.

For each species listed, the USFWS or the NMFS is supposed to prepare a recovery plan that includes designation and protection of critical habitat. Examples of successful recovery plans include those for the American alligator (Chapter 4 Core Case Study, p. 77), the gray wolf, the peregrine falcon, and the bald eagle.

The ESA also requires that all commercial shipments of wildlife and wildlife products enter or leave the country through one of nine designated ports. Only 120 full-time USFWS inspectors examine shipments of wild animals that enter the United States through these ports, airports, and border crossings. They can inspect only a small fraction of the more than 200 million wild animals brought legally into the United States each year. Also, tens of millions of such animals are brought in illegally, but few illegal shipments of endangered or threatened animals or plants are confiscated (Figure 9-23, p. 208). Even when they are caught, many violators are not prosecuted, and convicted violators often pay only a small fine.

In addition, people who smuggle or buy imported exotic animals are rarely aware that many of them carry dangerous infectious diseases, such as hantavirus, Ebola virus, Asian bird flu, herpes B virus (carried by most adult macaques), and salmonella (from pets such as hamsters, turtles, and iguanas), which can spread from pets to humans. The country's small number of wildlife inspectors does not have the capability or budget to detect such diseases.

Since 1982, the ESA has been amended to give private landowners economic incentives to help save endangered species living on their lands. The goal is to strike a compromise between the interests of private landowners and those of endangered and threatened species.

With one of these approaches, called a *habitat conservation plan* (HCP), a landowner, developer, or logger is allowed to destroy some critical habitat in exchange for taking steps to protect members of the species. Such measures might include setting aside a part of the species' habitat as a protected area, paying to relocate the species to another suitable habitat, or contributing money to have the government buy suitable habitat elsewhere. Once the plan is approved, it cannot be changed, even if new data show that the plan is inadequate to protect a species and help it recover. The ESA has also been used to protect endangered and threatened marine reptiles,

Steve Hillebrand/U.S. Fish and Wildlife Service.

Figure 9-23 Confiscated products made from endangered species. Because of a scarcity of funds and inspectors, probably no more than one-tenth of the illegal wildlife trade in the United States is discovered. The situation is even worse in most other countries.

such as turtles, and mammals, especially whales, seals, and sea lions, as discussed in Chapter 11.

Some believe that the Endangered Species Act should be weakened or repealed, and others believe it should be strengthened and modified to focus on protecting ecosystems. Opponents of the act contend that it puts the rights and welfare of endangered plants and animals above those of people. They argue that it has not been effective in protecting endangered species and has caused severe economic losses by hindering development on private lands. Since 1995, efforts to weaken the ESA have included the following suggested changes:

- Make protection of endangered species on private land voluntary.
- Have the government compensate landowners if they are forced to stop using part of their land to protect endangered species.
- Make it harder and more expensive to list newly endangered species by requiring government wildlife officials to navigate through a series of hearings and peer-review panels and requiring hard data instead of computer-based models.
- Eliminate the need to designate critical habitats.
- Allow the secretary of the interior to permit a listed species to become extinct without trying to save it.
- Allow the secretary of the interior to give any state, county, or landowner a permanent exemption from the law, with no requirement for public notification or comment.

Other critics would go further and do away with this act entirely. But because this step is politically unpopular with the American public, most efforts are designed to weaken the act and reduce its meager funding. In 2007, the USFWS issued a new interpretation of the ESA that would allow it to protect plants and animals only in areas where they are struggling to survive, rather than listing a species over its entire range. If this new policy survives court tests, it would remove about 80% of the roughly 1,350 U.S. species listed as endangered or threatened. Many wildlife biologists see this proposed policy as a deceptive way to gut the ESA by weakening existing protections and making it more difficult to list new species.

Most conservation biologists and wildlife scientists agree that the ESA needs to be simplified and streamlined. But they contend that it has not been a failure (Science Focus, at right).

We Can Establish Wildlife Refuges and Other Protected Areas

In 1903, President Theodore Roosevelt established the first U.S. federal wildlife refuge at Pelican Island, Florida, to help protect birds such as the brown pelican (see Photo 1 in the Detailed Contents) from extinction. Since then, the National Wildlife Refuge System has grown to include 547 refuges. Each year, more than 35 million Americans visit these refuges to hunt, fish, hike, and watch birds and other wildlife.

More than three-fourths of the refuges serve as wetland sanctuaries vital for protecting migratory waterfowl. One-fifth of U.S. endangered and threatened species have habitats in the refuge system, and some refuges have been set aside for specific endangered species (**Concept 9-5B**). These areas have helped Florida's key deer, the brown pelican, and the trumpeter swan to recover. According to a General Accounting Office study, however, activities considered harmful to wildlife occur in nearly 60% of the nation's wildlife refuges.

Conservation biologists call for setting aside more refuges for endangered plants. They also urge Congress and state legislatures to allow abandoned military lands that contain significant wildlife habitat to become national or state wildlife refuges.

Gene Banks, Botanical Gardens, and Wildlife Farms Can Help Protect Species

Gene or *seed banks* preserve genetic information and endangered plant species by storing their seeds in refrigerated, low-humidity environments (**Concept 9-4B**). More than 100 seed banks around the world collectively hold about 3 million samples.

SCIENCE FOCUS

Accomplishments of the Endangered Species Act

Critics of the ESA call it an expensive failure because only 37 species have been removed from the endangered list. Most biologists insist that it has not been a failure, for four reasons.

First, species are listed only when they face serious danger of extinction. This is like setting up a poorly funded hospital emergency room that takes only the most desperate cases, often with little hope for recovery, and saying it should be shut down because it has not saved enough patients.

Second, it takes decades for most species to become endangered or threatened. Not surprisingly, it also takes decades to bring a species in critical condition back to the point where it can be removed from the critical list. Expecting the ESA—which has been in existence only since 1973—to quickly repair the biological depletion of many decades is unrealistic.

Third, according to federal data, the conditions of more than half of the listed species are stable or improving, and 99% of the protected species are still surviving. A hospital emergency room taking only the most desperate cases and then stabilizing or improving the conditions of more than half of its patients and keeping 99% of them alive would be considered an astounding success.

Fourth, the ESA budget included only $58 million in 2005—about what the Department of Defense spends in a little more than an hour—or 20¢ per year per U.S. citizen. To its supporters, it is amazing that the ESA, on such a small budget, has managed to stabilize or improve the conditions of more than half of the listed species.

Its supporters would agree that the act can be improved and that federal regulators have sometimes been too heavy handed in enforcing it. But instead of gutting or doing away with the ESA, biologists call for it to be strengthened and modified to help protect ecosystems and the nation's overall biodiversity.

A study by the U.S. National Academy of Sciences recommended three major changes to make the ESA more scientifically sound and effective:

- Greatly increase the meager funding for implementing the act.
- Develop recovery plans more quickly. A 2006 study by the Government Accountability Office, found that species with recovery plans have a better chance of getting off the endangered list, and it recommended that any efforts to reform the law should continue to require recovery plans.
- When a species is first listed, establish a core of its survival habitat as critical, as a temporary emergency measure that could support the species for 25–50 years.

Most biologists and wildlife conservationists believe that the United States needs a new law that emphasizes protecting and sustaining biological diversity and ecosystem functioning (**Concept 9-4A**) rather than focusing mostly on saving individual species. We discuss this idea further in Chapter 10.

Critical Thinking

Should the U.S. Endangered Species Act be modified to more effectively protect and sustain the nation's overall biodiversity? Explain.

Scientists urge the establishment of many more such banks, especially in developing countries. But some species cannot be preserved in gene banks. The banks are also expensive to operate and can be destroyed by fires and other mishaps.

The world's 1,600 *botanical gardens* and *arboreta* contain living plants representing almost one-third of the world's known plant species. However, they contain only about 3% of the world's rare and threatened plant species and have too little space and funding to preserve most of those species.

We can take pressure off some endangered or threatened species by raising individuals on *farms* for commercial sale. Farms in Florida raise alligators for their meat and hides. Butterfly farms flourish in Papua New Guinea, where many butterfly species are threatened by development activities.

Zoos and Aquariums Can Protect Some Species

Zoos, aquariums, game parks, and animal research centers are being used to preserve some individuals of critically endangered animal species, with the long-term goal of reintroducing the species into protected wild habitats (**Concept 9-4B**).

Two techniques for preserving endangered terrestrial species are egg pulling and captive breeding. *Egg pulling* involves collecting wild eggs laid by critically endangered birds and then hatching them in zoos or research centers. In *captive breeding,* some or all of the wild individuals of a critically endangered species are captured for breeding in captivity, with the aim of reintroducing the offspring into the wild. Captive breeding has been used to save the peregrine falcon and the California condor (Case Study, p. 210).

Other techniques for increasing the populations of captive species include artificial insemination, embryo transfer (surgical implantation of eggs of one species into a surrogate mother of another species), use of incubators, and cross-fostering (in which the young of a rare species are raised by parents of a similar species). Scientists also use computer databases, which hold information on family lineages of species in zoos, and DNA analysis to match individuals for mating—a computer dating service for zoo animals—and to prevent genetic erosion through inbreeding.

The ultimate goal of captive breeding programs is to build up populations to a level where they can be reintroduced into the wild. But after more than two

decades of captive breeding efforts, only a handful of endangered species have been returned to the wild. Examples shown in Figure 9-3 include the black-footed ferret, the California condor (Case Study, right), and the golden lion tamarin. Most reintroductions fail because of lack of suitable habitat, inability of individuals bred in captivity to survive in the wild, renewed overhunting, or poaching of some of the returned individuals.

Lack of space and money limits efforts to maintain breeding populations of endangered animal species in zoos and research centers. The captive population of each species must number 100–500 individuals to avoid extinction through accident, disease, or loss of genetic diversity through inbreeding. Recent genetic research indicates that 10,000 or more individuals are needed for an endangered species to maintain its capacity for biological evolution.

Public aquariums that exhibit unusual and attractive fish and some marine animals such as seals and dolphins help to educate the public about the need to protect such species. But mostly because of limited funds, public aquariums have not served as effective gene banks for endangered marine species, especially marine mammals that need large volumes of water.

Instead of seeing zoos and aquariums as sanctuaries, some critics claim that most of them imprison once-wild animals. They also contend that zoos and aquariums can foster the false notion that we do not need to preserve large numbers of wild species in their natural habitats. Proponents counter that these facilities play an important role in educating the public about wildlife and the need to protect biodiversity.

Regardless of their benefits and drawbacks, zoos, aquariums, and botanical gardens are not biologically or economically feasible solutions for the growing problem of premature extinction of species. Figure 9-24 lists some things you can do to deal with this problem.

WHAT CAN YOU DO?

Protecting Species

- Do not buy furs, ivory products, or other items made from endangered or threatened animal species
- Do not buy wood or paper products produced by cutting old-growth forests in the tropics
- Do not buy birds, snakes, turtles, tropical fish, and other animals that are taken from the wild
- Do not buy orchids, cacti, or other plants that are taken from the wild
- Spread the word. Talk to your friends and relatives about this problem and what they can do about it

Figure 9-24 Individuals matter: ways to help prevent premature extinction of species. **Question:** Which two of these suggestions do you believe are the most important? Why?

■ **CASE STUDY**

Trying to Save the California Condor

At one time the California condor (Figure 9-4), North America's largest bird, was nearly extinct with only 22 birds remaining in the wild. To save the species, one approach was to capture the remaining birds and breed them in captivity at zoos.

The captured birds were isolated from human contact as much as possible, and to reduce genetic defects, closely related individuals were prevented from breeding. As of 2007, 135 condors had been released back into the wild throughout the southwestern United States.

A major threat to these birds is lead poisoning resulting when they ingest lead pellets from ammunition in animal carcasses or gut piles left behind by hunters. A lead-poisoned condor quickly becomes weak and mentally impaired and dies of starvation, or is killed by predators.

A coalition of conservationist and health organizations is lobbying state game commissions and legislatures to ban the use of lead in ammunition and to require use of less harmful substitutes. They also urge people who hunt in condor ranges to remove all killed animals or to hide carcasses and gut piles by burying them, covering them with brush or rocks, or putting them in inaccessible areas.

THINKING ABOUT

The California Condor's Comeback

CORE CASE STUDY

What are some differences between the stories of the condor and the passenger pigeon (**Core Case Study**) that might give the condor a better chance of avoiding premature extinction than the passenger pigeon had?

The Precautionary Principle

Some might argue that, because we have identified fewer than 2 million of the estimated 5–100 million species on the earth, it makes little sense to take drastic measures to preserve them.

Conservation biologists disagree. They remind us that the earth's species are the primary components of its biodiversity, which should not be degraded because of the economic and ecological services it provides. They call for us to use great caution in making potentially harmful changes to communities and ecosystems and to take precautionary action to help *prevent* poten-

tially serious environmental problems, including premature extinctions.

This approach is based on the **precautionary principle:** When substantial preliminary evidence indicates that an activity can harm human health or the environment, we should take precautionary measures to prevent or reduce such harm, even if some of the cause-and-effect relationships have not been fully established, scientifically (**Concept 9-4C**). It is based on the commonsense idea behind many adages such as "Better safe than sorry" and "Look before you leap."

Scientists use the precautionary principle to argue for preservation of species, and also for preserving entire ecosystems, which is the focus of the next two chapters.

REVISITING

Passenger Pigeons and Sustainability

CORE CASE STUDY

SUSTAINABILITY

The disappearance of the passenger pigeon (**Core Case Study**) in a short time was a blatant example of the effects of activities undertaken by uninformed or uncaring people. Since the passenger pigeon became extinct, we have learned a lot about how to protect birds and other species from premature extinction resulting from our activities. We have also learned much about the importance of wild species as key components of the earth's biodiversity and of the natural capital that supports all life and economies.

Yet, despite these efforts, there is overwhelming evidence that we are in the midst of wiping out as many as half of the world's wild species within your lifetime. Ecological ignorance accounts for some of the failure to deal with this problem. But to many, the real cause of this failure is political. They would argue that we lack the will to act on our scientific knowledge and our ethical judgments.

In keeping with the four **scientific principles of sustainability** (see back cover), acting to prevent the premature extinction of species helps to preserve the earth's biodiversity and to maintain species interactions that help control population sizes, energy flow, and matter cycling in ecosystems. Thus it is not only for the species that we ought to act, but also for the overall long-term health of the biosphere on which we all depend, and for the health and well-being of our own species. Protecting wild species and their habitats is a way of protecting ourselves and our descendants.

The problem is complex, and so are the solutions. Protecting biodiversity is no longer simply a matter of passing and enforcing endangered species laws and setting aside parks and preserves. It will also require slowing climate change, which will affect many species and their habitats. And it will require reducing the size and impact of our ecological footprints (Figure 1-10, p. 15). Although the solutions to biodiversity loss and degradation are complex, they are well within our reach.

The great challenge of the twenty-first century is to raise people everywhere to a decent standard of living while preserving as much of the rest of life as possible.

EDWARD O. WILSON

REVIEW

1. Review the Key Questions and Concepts for this chapter on p. 184. What factors led to the premature extinction of the passenger pigeon in the United States?
2. Distinguish between **background extinction** and **mass extinction.** What is the **extinction rate** of a species? Describe how scientists estimate extinction rates. Give four reasons why many extinction experts believe that human activities are now causing a sixth mass extinction. Distinguish between **endangered species** and **threatened species.** List some characteristics that make some species especially vulnerable to extinction.
3. What are two reasons for trying to prevent the premature extinction of wild species? What is the **instrumental value** of a species? List six types of instrumental values provided by wild species. How are scientists using DNA analysis to reduce the illegal killing of elephants? What is the **intrinsic (existence) value** of a species?
4. What is biophilia? Why should we care about bats?
5. What is **HIPPCO?** In order, what are the six largest causes of premature extinction of species resulting from human activities? Why are island species especially vulnerable to extinction? What is habitat fragmentation, and how does it threaten many species?
6. Describe the threats to bird species in the world and in the United States. List three reasons why we should be alarmed by the decline of bird species.

7. Give two examples of the harmful effects of nonnative species that have been introduced **(a)** deliberately and **(b)** accidentally. List ways to limit the harmful impacts of nonnative species. Describe the roles of population growth, overconsumption, pollution, and climate change in the premature extinction of wild species. Describe what is happening to many of the honeybees in the United States and what economic and ecological roles they play. Explain how pesticides such as DDT can be biomagnified in food chains and webs. Explain how global warming is threatening polar bears.

8. Describe the poaching of wild species and give three examples of species that are threatened by this illegal activity. Describe the work of Jane Goodall in protecting wild primates. Why are tigers likely to disappear from the wild by the end of this century? Describe the threat to some forms of wildlife from increased hunting for bush meat.

9. Describe two international treaties that are used to help protect species. Describe the U.S. Endangered Species Act, how successful it has been, and the controversy over this act. Describe the roles of wildlife refuges, gene banks, botanical gardens, wildlife farms, zoos, and aquariums in protecting some species.

10. Describe how protecting wild species from premature extinction (**Core Case Study**) is in keeping with the four **scientific principles of sustainability**.

Note: Key Terms are in **bold** type.

CRITICAL THINKING

1. List three ways in which you could apply **Concept 9-3** to make your lifestyle more environmentally sustainable.

2. What are three aspects of your lifestyle that directly or indirectly contribute to the premature extinction of some bird species (Case Study, p. 195)? What are three things that you think should be done to reduce the premature extinction of birds?

3. Discuss your gut-level reaction to the following statement: "Eventually, all species become extinct. Thus, it does not really matter that the passenger pigeon (**Core Case Study**) is extinct, and that the whooping crane and the world's remaining tiger species are endangered mostly because of human activities." Be honest about your reaction, and give arguments for your position.

4. Do you accept the ethical position that each species has the inherent right to survive without human interference, regardless of whether it serves any useful purpose for humans? Explain. Would you extend this right to the *Anopheles* mosquito, which transmits malaria, and to infectious bacteria? Explain.

5. Wildlife ecologist and environmental philosopher Aldo Leopold wrote, "To keep every cog and wheel is the first precaution of intelligent tinkering." Explain how this statement relates to the material in this chapter. Explain how protecting wild species and their habitats is an important way to protect the health and well-being of people.

6. What would you do if **(a)** your yard and house were invaded by fire ants, **(b)** you found bats flying around your yard at night, and **(c)** deer invaded your yard and ate your shrubs, flowers, and vegetables?

7. Which of the following statements best describes your feelings toward wildlife?
   - **a.** As long as it stays in its space, wildlife is okay.
   - **b.** As long as I do not need its space, wildlife is okay.
   - **c.** I have the right to use wildlife habitat to meet my own needs.
   - **d.** When you have seen one redwood tree, elephant, or some other form of wildlife, you have seen them all, so lock up a few of each species in a zoo or wildlife park and do not worry about protecting the rest.
   - **e.** Wildlife should be protected.

8. Environmental groups in a heavily forested state want to restrict logging in some areas to save the habitat of an endangered squirrel. Timber company officials argue that the well-being of one type of squirrel is not as important as the well-being of the many families who will be affected if the restriction causes the company to lay off hundreds of workers. If you had the power to decide this issue, what would you do and why? Can you come up with a compromise?

9. Congratulations! You are in charge of preventing the premature extinction, caused by human activities, of the world's existing species. What are three things you would do to accomplish this goal?

10. List two questions that you would like to have answered as a result of reading this chapter.

Note: See Supplement 13 (p. S78) for a list of Projects related to this chapter.

DATA ANALYSIS

Examine these data released by the World Resources Institute and answer the following questions.

Country	Total Land Area in Square Kilometers (square miles)	Protected Area as Percent of Total Land Area (2003)	Total Number of Known Breeding Bird Species (1992–2002)	Number of Threatened Breeding Bird Species (2002)	Threatened Breeding Bird Species as Percent of Total Number of Known Breeding Bird Species
Afghanistan	647,668 (250,000)	0.3	181	11	
Cambodia	181,088 (69,900)	23.7	183	19	
China	9,599,445 (3,705,386)	7.8	218	74	
Costa Rica	50,110 (19,730)	23.4	279	13	
Haiti	27,756 (10,714)	0.3	62	14	
India	3.287,570 (1,269,388)	5.2	458	72	
Rwanda	26,344 (10,169)	7.7	200	9	
United States	9,633,915 (3,781,691)	15.8	508	55	

Source: Data from **earthtrends.wri.org/country_profiles/index.php?theme=7**.
World Resources Institute, *Earth Trends, Biodiversity and Protected Areas, Country Profiles*

1. For each of the eight countries, complete the table by filling in the last column.
2. Arrange the countries from largest to smallest according to Total Land Area. Does there appear to be any correlation between the size of country and the percentage of Threatened Breeding Bird Species? Explain your reasoning.

LEARNING ONLINE

Log on to the Student Companion Site for this book at **academic.cengage.com/biology/miller**, and choose Chapter 9 for many study aids and ideas for further reading and research. These include flash cards, practice quizzing, Weblinks, information on Green Careers, and InfoTrac® College Edition articles.