CHAPTER 7

Biodiversity and Conservation

Lesson 1
Our Planet of Life

Lesson 2
Extinction and Biodiversity Loss

Lesson 3
Protecting Biodiversity

Siberian tiger
(Panthera tigris altaica)

SAVING the Siberian Tiger

Central CASE

WHAT COMES TO MIND when someone says "tiger"? Adjectives like *powerful, beautiful,* and *deadly* are certainly fitting, but chances are you also thought of something like *endangered* or *rare.* It wasn't always this way. Tigers (scientific name *Panthera tigris*) used to roam all over Asia, from Turkey to northeast Russia to Indonesia. Within the past 200 years, however, humans have driven tigers from most of their historic range. Three subspecies have already been lost forever; the remaining five subspecies are in danger of following them to extinction.

The largest surviving tiger subspecies is the Siberian tiger *(Panthera tigris altaica),* also known as the Amur tiger after the river that runs through their habitat. Males of this variety can reach 3.7 meters (12 feet) in length and weigh up to 360 kilograms (800 pounds). Siberian tigers live in the remote forests of the Sikhote-Alin Mountains in easternmost Russia. For thousands of years, Siberian tigers coexisted with the region's native people. Called "Old Man" or "Grandfather," Siberian tigers were viewed as guardians of the mountains and forests, and were only killed when they had preyed on a person.

Settlers to the region in the early twentieth century, however, had no such cultural traditions. They hunted tigers for sport and hides. Soon, there was a market for tiger skins, bones, and meat—especially in China and other Asian countries where tiger parts are used in traditional forms of medicine. Suddenly, dead tigers were worth a lot of money. At the same time, road building, logging, and agriculture fragmented the tiger's habitat and provided easy access for hunters. The wild Siberian tiger population plummeted to just 20–30 animals.

Eventually, international conservation groups got involved, working with Russian biologists to save the remaining tigers. One such group was the Hornocker Wildlife Institute, now part of the Wildlife Conservation Society (WCS). In 1992, the group helped launch the Siberian Tiger Project, devoted to studying the tiger and its habitat. The team worked closely with people living near an area of tiger habitat, educating them about the importance and value of their big cat neighbors.

Today, WCS biologists use radio collars to track tigers, monitor their health, and determine causes of death when they die. They also provide funding for local wildlife officials to protect the tigers from hunters.

Thanks to such efforts, there are around 450–500 Siberian tigers in the wild today. About 500 more survive in zoos and captive breeding programs around the world. Hunting is still common, however, and there is no guarantee that the Siberian tiger population will continue to climb. Unfortunately many similar struggles to halt biodiversity loss are occurring all over the world.

BIG QUESTION

Q: Why is it important to protect biodiversity?

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- Extend the Reading
- Take It Local
- 3-D Geo Tour

LESSON 1

Our Planet of Life

Guiding Question: What is biodiversity?

Knowledge and Skills

- Differentiate the components of biodiversity.
- Explain two ways in which biodiversity varies across groups or geography.
- Describe the economic benefits of biodiversity.

Reading Strategy and Vocabulary

Reading Strategy Before you read, set up a main idea and details chart for this lesson. Use the blue headings for main ideas. As you read, fill in supporting details from the text.

Vocabulary biodiversity, species diversity, genetic diversity, ecosystem diversity

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7.1 LESSON PLAN PREVIEW

Differentiated Instruction Help struggling students organize information about genetic, species, and ecosystem diversity.

Inquiry Use a globe to help students visualize the latitudinal gradient.

Real World Groups identify ways biodiversity enhances their lives.

7.1 RESOURCES

Outdoors Lab, *Exploring Plant Diversity* • Lesson 7.1 Worksheets • Lesson 7.1 Assessment • Chapter 7 Overview Presentation

SCIENTISTS WORLDWIDE are confirming what most people have suspected for a long time: many once-thriving species are disappearing. This suggests the question, "Does it matter?" There are a number of ways to answer that—from the practical to the ethical. To formulate your own answer, it is important to understand just how much life there is on our planet and what might happen if it is lost forever.

Biodiversity

Species diversity, genetic diversity, and ecosystem diversity are all parts of an area's overall biodiversity.

From tigers to tiger beetles, Earth is full of life. The variety of life across all levels of ecological organization is called **biodiversity.** Overall biodiversity, whether of an isolated population of organisms or the entire biosphere, includes genetic diversity, species diversity, and ecosystem diversity, as seen in **Figure 1.** Of these levels of biodiversity, the most commonly used and easiest to visualize is species diversity.

Genetic diversity Genetic diversity describes the differences in DNA among individuals of a population or species.

Species diversity The number or variety of species in a given area is known as species diversity.

Ecosystem diversity An area's ecosystem diversity refers to its variety of ecosystems, communities, or habitats.

FIGURE 1 **Levels of Biodiversity** The concept of biodiversity encompasses several levels in the hierarchy of life.

Species Diversity Recall that members of a species share certain characteristics, including similar DNA, and can breed with one another to produce fertile offspring. **Species diversity** is the number or variety of species in a particular region. There is currently a massive project underway, called the *Encyclopedia of Life*, that is attempting to provide an accessible online library of worldwide species diversity.

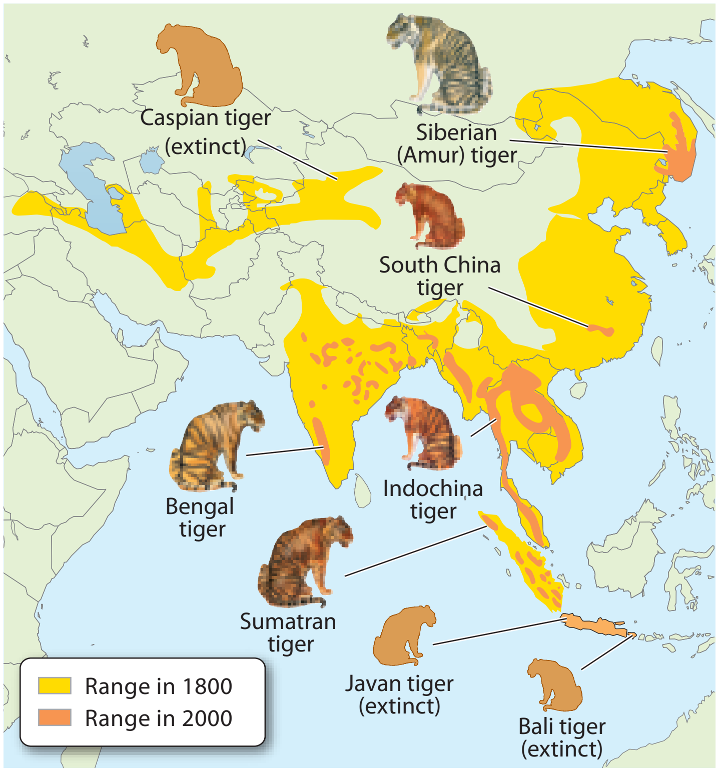
Speciation generates new species, adding to species diversity, whereas extinction decreases species diversity. Although immigration and emigration may increase or decrease species diversity locally, only speciation and extinction change it globally.

▶ ***Classifying Species*** *Taxonomists,* the scientists who classify species, use an organism's physical appearance and genetic makeup to determine its species. Species are then placed within a hierarchy of categories, called *taxonomic groups,* that reflect evolutionary relationships. Closely related species are grouped together into *genera* (singular, *genus*). In traditional classification, there are five taxonomic groups above the level of genus: family, order, class, phylum, and kingdom. As our knowledge of evolutionary relationships increases, however, there have been some changes to the system. For example, many scientists now use a taxonomic group even larger than the kingdom, called the domain, to classify phyla.

Every species is given a two-part scientific name denoting its genus and species. The tiger, *Panthera tigris,* differs from the world's other species of large cats, such as the jaguar (*Panthera onca*), the leopard (*Panthera pardus*), and the African lion (*Panthera leo*). These four species are closely related in evolutionary terms, as indicated by the genus name they share, *Panthera.* They are more distantly related to cats in other genera such as the cheetah (*Acinonyx jubatus*) and the bobcat (*Felis rufus*), although all cats are classified together in the family Felidae.

▶ ***Classification Below the Species Level*** Below the species level organisms may be classified into subspecies. A *subspecies* is a population of organisms that has genetically based characteristics, such as size or color, that differ from members of the same species in a different area. Subspecies are formed by the same processes that drive speciation. However, divergences stop short of producing separate species. Scientists denote subspecies with a third part of the scientific name. The Siberian tiger, *Panthera tigris altaica,* is one of five subspecies of tiger still surviving, as shown in **Figure 2.** Tiger subspecies differ in color, coat thickness, stripe patterns, and size, but could interbreed if they lived together.

Reading Checkpoint *What is a subspecies?*



Data from the Tiger Information Center.

Connect to the Central Case

FIGURE 2 Subspecies Deforestation, hunting, and other pressures have caused tigers to disappear from most of the geographic range they historically occupied. This map contrasts the ranges of the eight tiger subspecies in the years 1800 (yellow) and 2000 (orange). **Interpret Maps** Which tiger subspecies are extinct?

ANSWERS

Reading Checkpoint A population of organisms that has different inherited characteristics from members of the same species in a different area

Figure 2 Caspian tiger, Javan tiger, and Bali tiger

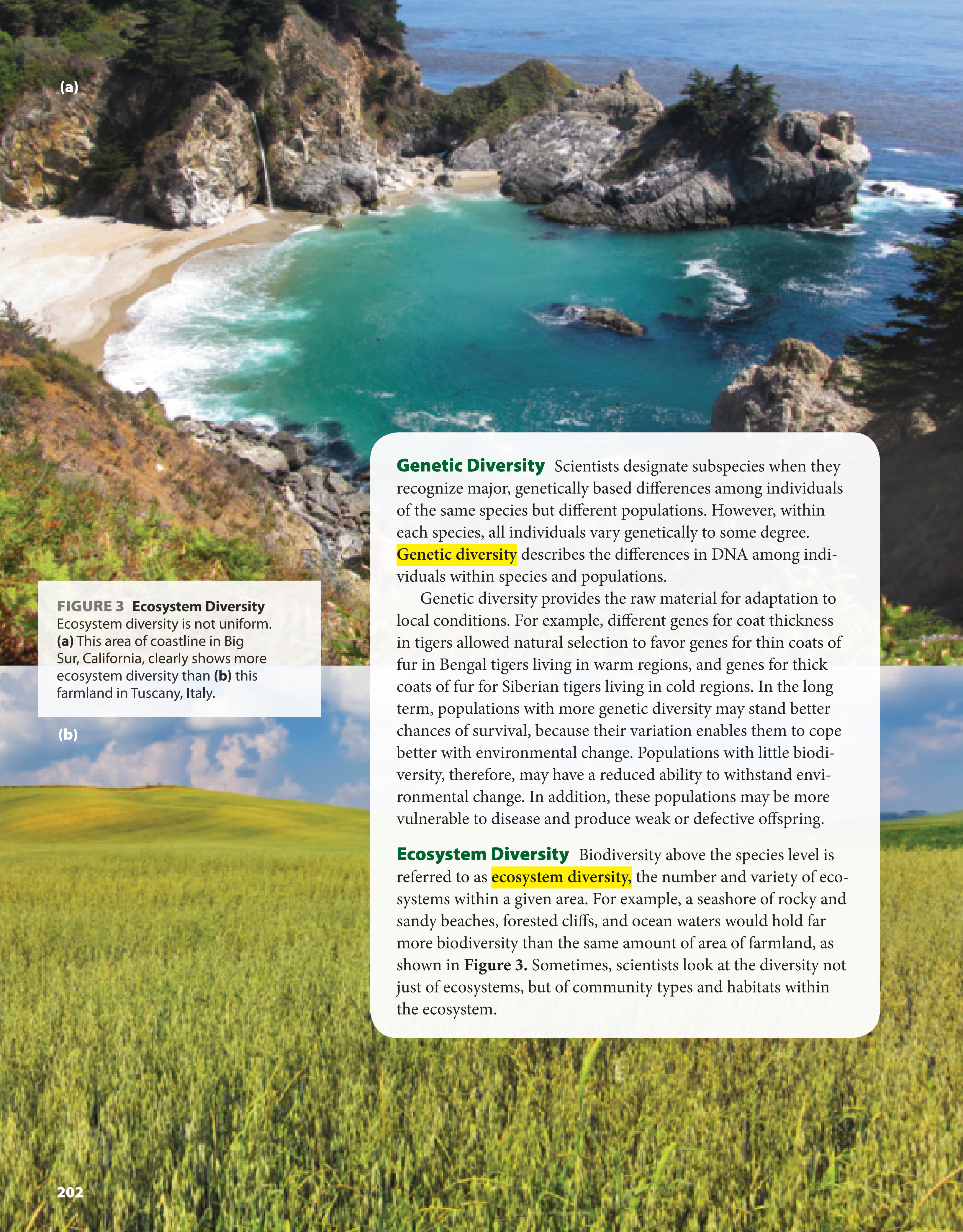


FIGURE 3 Ecosystem Diversity Ecosystem diversity is not uniform. **(a)** This area of coastline in Big Sur, California, clearly shows more ecosystem diversity than **(b)** this farmland in Tuscany, Italy.

Genetic Diversity Scientists designate subspecies when they recognize major, genetically based differences among individuals of the same species but different populations. However, within each species, all individuals vary genetically to some degree. **Genetic diversity** describes the differences in DNA among individuals within species and populations.

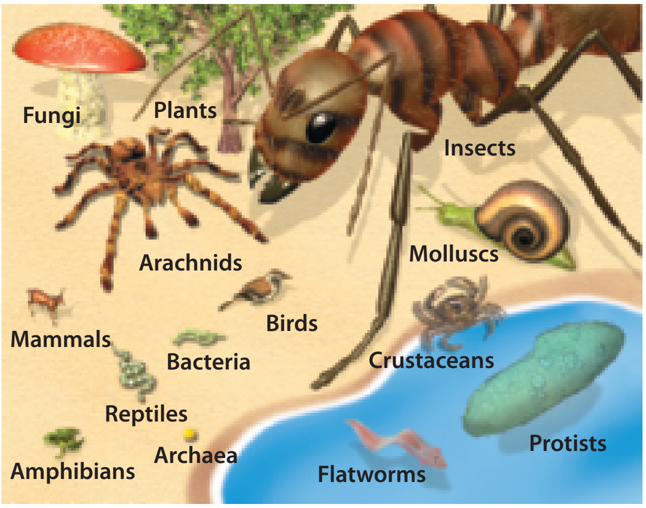
Genetic diversity provides the raw material for adaptation to local conditions. For example, different genes for coat thickness in tigers allowed natural selection to favor genes for thin coats of fur in Bengal tigers living in warm regions, and genes for thick coats of fur for Siberian tigers living in cold regions. In the long term, populations with more genetic diversity may stand better chances of survival, because their variation enables them to cope better with environmental change. Populations with little biodiversity, therefore, may have a reduced ability to withstand environmental change. In addition, these populations may be more vulnerable to disease and produce weak or defective offspring.

Ecosystem Diversity Biodiversity above the species level is referred to as **ecosystem diversity,** the number and variety of ecosystems within a given area. For example, a seashore of rocky and sandy beaches, forested cliffs, and ocean waters would hold far more biodiversity than the same amount of area of farmland, as shown in **Figure 3.** Sometimes, scientists look at the diversity not just of ecosystems, but of community types and habitats within the ecosystem.

Biodiversity Distribution

Biodiversity varies among taxonomic groups and geographic regions.

Coming up with precise ways to express a region's biodiversity is difficult. Scientists often express biodiversity in terms of its most easily measured component, species diversity. But counting species is a lot harder than it sounds, and scientists still can only estimate the total species richness of our planet.



Data from Groombridge, B., and M.D. Jenkins, 2002. ***Global biodiversity: Earth's living resources in the 21st century.*** UNEP-World Conservation Monitoring Centre. Cambridge, U.K.: Hoechst Foundation.

FIGURE 4 Where Insects Are King This illustration shows organisms scaled in size to the number of species known in several major groups, giving a visual sense of the difference in their species diversity. However, scientists think that many species have not been described or even discovered. So, some groups (such as bacteria, archaea, insects, flatworms, protists, fungi, and others) most likely contain far more species than we now know about.

Measuring Biodiversity Species are not evenly distributed among taxonomic groups. Although most insects are small, in terms of number of known and described species, they dwarf all other forms of life, as shown in **Figure 4.** Among known insects, about 40 percent are beetles. A scientist from the Smithsonian Institution named Terry Erwin fogged rainforest trees in Central America with clouds of insecticide and then collected organisms as they died and fell from the treetops. His results, published in 1982, include finding 1200 species of beetle living on 19 trees of the same species. Of those, he concluded that 163 of the beetle species lived *only* on that particular species of tree.

So far, scientists have identified and described 1.7 million to 2 million species of plants, animals, fungi, and microorganisms. However, using a variety of methods, including tree fogging, scientists estimate the total number of species that actually exists is far greater. Most estimates are in the range of 3 million to 100 million, with best-educated guesses spanning from 5 million to 30 million. Why do these estimates vary so much? First, some areas of Earth, such as the deepest ocean, remain relatively unexplored. Second, many species, such as bacteria and many fungi, are tiny and easily overlooked. Third, many organisms are extremely difficult to identify and tell apart from other species. This is frequently the case with microbes, fungi, and small insects, but also sometimes with organisms as large as birds, trees, and whales.

Patterns of Biodiversity In addition to being unevenly distributed across organism groups, living things are also unevenly distributed across our planet. For example, there is a general increase in species richness toward the equator. This pattern of variation with latitude, called the *latitudinal gradient,* is one of the most obvious and striking patterns in ecology.

At smaller scales, diversity patterns vary with habitat type. Generally, habitats that are structurally diverse have more ecological niches and support greater species richness. For instance, forests usually support greater diversity than grasslands. For any given geographic area, species diversity tends to increase with diversity of habitats because each habitat supports a somewhat different community of organisms.

Reading Checkpoint *Why don't scientists know exactly how many species there are on Earth?*

ANSWERS

Reading Checkpoint It is hard to determine exactly how many species are on Earth because some areas of Earth are relatively unexplored, some species are easy to overlook, and some species are difficult to distinguish from one another.

your world • your turn

WHAT DO YOU THINK?

Companies search the world for organisms that can provide new drugs, foods, medicines, or other valuable products. If a company discovers a compound that could be turned into a billion-dollar drug, who should benefit? Do you think the company should have to share any profits with the country in which it found the drug? Or, should the company get to keep all of the money because it made the discovery and performed the research?

ANSWERS

What Do You Think? Answers will vary. Responses should indicate an understanding of the economic value of biodiverse ecosystems.

Benefits of Biodiversity

Biodiverse ecosystems provide economically valuable services and products.

Contrary to popular opinion, some things in life can indeed be free. Intact ecosystems provide valuable processes, known as *ecosystem services,* for all of us free of charge. The United Nations Environment Programme (UNEP) identifies ecosystem services provided by biodiversity, including purification of air and water, control of pests and diseases, and decomposition of wastes. Biodiversity also provides food, fuel, and fiber. One 1997 study published in the journal *Nature* estimated that Earth's ecosystems, such as the wetland in **Figure 5,** provide at least $33 trillion worth of ecosystem services a year.

Biodiversity and Ecosystem Function Functioning ecosystems are clearly important, but what does biodiversity have to do with it? Ecologists are finding that high levels of biodiversity tend to increase the stability of communities and ecosystems. An ecosystem is considered stable if it is both resistant and resilient. *Resistant* ecosystems can resist environmental change without losing function. *Resilient* ecosystems are affected by change but can bounce back and regain function. Most of the research on ecosystem stability has dealt with species diversity, but new work is finding that high genetic diversity can also have a stabilizing effect on ecosystems. Thus, a loss of biodiversity at any level could decrease a natural system's ability to function and provide services to our society.

What about the extinction of individual species? Ecological research suggests that this depends on which species are removed. Ecosystems are complex, and it is difficult to predict which particular species may be important. Removing a species that can be replaced by others—one grazing herbivore for another grazing herbivore, for example—may make little difference. Recall, however, that removal of a keystone species results in significant changes in an ecological system.

FIGURE 5 Ecosystem Goods and Services This wetland in Georgia naturally purifies the water that flows through it—just one of the many ecosystem services it provides.

FIGURE 6 Biodiversity's Benefits Nature provides us with a variety of resources—some we have only begun to use. **(a)** The fruit of the babassu palm produces large quantities of oil that can be used for everything from cooking to fuel. **(b)** Medicines derived from the rosy periwinkle are used to treat two forms of life-threatening cancer.

Top predators, such as tigers, are often considered keystone species because a single individual may prey on many other carnivores, each of which may prey on many herbivores. In turn, each herbivore may consume many plants. Thus the removal of a top predator produces effects that multiply as they cascade down the food web, ultimately changing how the ecosystem functions. Similarly, removal of a species at the base of a food web can set huge changes in motion. In Antarctica, almost all life is indirectly dependent upon microscopic, photosynthetic algae that grow beneath the ice—without them, the whole food web collapses.

Biodiversity and Agriculture Biodiversity, especially genetic diversity, benefits agriculture. Wild strains can be cross-bred with their crop plant relatives, passing on traits such as pest resistance in the process. During the 1970s, for example, a researcher discovered a maize species in Mexico known as *Zea diploperennis*. This maize is highly resistant to disease, and it is a perennial, meaning it will grow back year after year without being replanted. Plant breeders can cross-breed *Zea diploperennis* with other maize species to create a variety of disease-resistant, perennial hybrids. In addition, scientists continue to discover new plants that have potential for widespread use. The babassu palm *(Orbignya phalerata)* in **Figure 6a,** for example, yields more vegetable oil than either coconut or palm nuts. The oil, similar to coconut oil, can be used for cooking, fuel, and many industrial processes.

Biodiversity and Medicine Every species that goes extinct represents a lost opportunity to find a cure for a disease. The rosy periwinkle *(Catharanthus roseus)* in **Figure 6b,** for example, produces compounds that treat Hodgkin's lymphoma and a particularly deadly form of leukemia. Had this native plant of Madagascar become extinct before its discovery by medical researchers, these deadly diseases would have claimed far more victims. Many other common medicines come from plants, such as the cancer drugs colchicine and paclitaxel, the heart medicine digitoxin, and the antimalarial drug quinine. In fact, of the 150 most often prescribed drugs in the United States, 118 originate from nature, not from labs.

Reading Checkpoint *How can the extinction of a single species affect how an ecosystem functions?*

BIG QUESTION

Why is it important to protect biodiversity?

Perspective Have students write a short paragraph explaining the importance of preserving biodiversity from the point of view of one of the following: a medical researcher, a farmer, a professional chef, an ecotourist, or an organism (other than a human) in an ecosystem. Have several students share their completed paragraphs with the class. Wrap up the activity with a brief discussion emphasizing the many reasons why it is important to protect biodiversity.

ANSWERS

Reading Checkpoint Extinction of even a single keystone species will cause significant change to the ecosystem. Extinction of a species that is easily replaced by others may have little impact.

FIGURE 7 **Ecotourism** Ecotourism can bring millions of dollars into a nation's economy. Here, a tourist is photographing cheetahs on the Masai Mara Game Reserve in Kenya.

Biodiversity, Tourism, and Recreation

Besides providing for our food and health, biodiversity can be a direct source of income. *Ecotourism* describes environmentally responsible travel to protected natural areas for the purpose of appreciating nature, promoting conservation, and providing economic benefits to local peoples. Ecotourism is different from tourism because it emphasizes conservation, education, sustainability, and community participation.

Ecotourism has become a vital source of income for nations such as Costa Rica, with its rain forests; Australia, with its Great Barrier Reef; Belize, with its reefs, caves, and rain forests; and Kenya and Tanzania, with their savanna wildlife. The United States, too, benefits from ecotourism. American national parks, for example, draw millions of visitors each year from around the world.

Money from ecotourism provides a good reason for nations, states, and local communities to preserve natural areas and species. However, critics have warned that too many visitors to natural areas can disturb and harm wildlife. As ecotourism continues to increase, so will debate over its costs and benefits for local communities and for biodiversity.

ANSWERS

Lesson 1 Assessment For answers to the Lesson 1 Assessment, see page A–10 at the back of the book.

LESSON 1 Assessment

1. **Contrast** Explain the differences among genetic diversity, species diversity, and ecosystem diversity.
2. **Apply Concepts** Do the location and general biodiversity of tropical rain forests and boreal forests agree with what you would predict according to the latitudinal gradient pattern? Explain your answer. (*Hint:* You may want to refer to the biome map in the previous chapter.)
3. **Form an Opinion** You are trying to convince a friend about the importance of protecting biodiversity. Which one of the economic benefits discussed (ecosystem function, agricultural, medical, recreational) makes the strongest argument? Why?
4. Explore the **BIG**QUESTION Scientists are worried about the future of some species that have experienced extreme decreases in both population size and genetic diversity, including cheetahs, bison, and elephant seals. Using the concept of genetic diversity, explain why these animals may be in trouble even if their population sizes have increased in recent years.

Extinction and Biodiversity Loss

LESSON 2

Guiding Question: Why is global biodiversity decreasing?

Knowledge and Skills

- Describe how biodiversity is monitored and explain current biodiversity trends.
- List the major causes of biodiversity loss.

Reading Strategy and Vocabulary

Reading Strategy As you read this lesson, fill out a cause-and-effect diagram for biodiversity loss. Remember that one cause can have multiple effects.

Vocabulary extirpation, endangered species, threatened species, habitat fragmentation, poaching

BIODIVERSITY LOSSES caused by humans are common throughout history. Archaeological evidence shows that waves of extinctions tend to follow whenever people colonize islands and continents. After the Polynesians reached Hawaii, for example, half its birds went extinct. Birds, mammals, and reptiles vanished following the colonization of New Zealand and Madagascar. Dozens of species of large vertebrates died off in Australia after the Aborigines arrived roughly 50,000 years ago. North America lost 33 genera of large mammals after people arrived on the continent 10,000 years ago. Why does human settlement seem to mean extinction for other organisms? And, more important, is there anything we can do about it?

Biodiversity at Risk

Scientists monitor biodiversity closely and have noticed significantly higher than normal extinction rates in recent decades.

Once extinct, a species can never return. Recall that extinction occurs when the last member of a species dies. The disappearance of a particular population from a given area, but not of the entire species globally, is called **extirpation.** The tiger has been extirpated from most of its historic range, but it is not yet extinct. However, as populations become extirpated, the species as a whole is pushed closer and closer to extinction.

Natural Biodiversity Loss If organisms did not naturally go extinct, dinosaurs might be the main attraction at your local zoo. Extinctions usually occur one by one at a pace that paleontologists and other scientists refer to as the *background rate of extinction.* Before modern humans evolved, for example, the fossil record indicates that about one of every 1000 mammal species would typically go extinct every 1000–10,000 years. This means that, before humans, approximately one mammal species out of every 1 million to 10 million went extinct per year.

There have been times, however, when extinction rates have been far above the normal background rate. These events, called *mass extinctions,* have occurred at least five times in Earth's history. Each time more than one fifth of all families and half of all species have gone extinct.

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7.2 LESSON PLAN PREVIEW

Real World Groups research and share information about local endangered species.

Differentiated Instruction Less proficient readers each summarize a cause of biodiversity loss.

7.2 RESOURCES

Modeling Lab, *Overharvesting* • Map It Online • Lesson 7.2 Worksheets • Lesson 7.2 Assessment • Chapter 7 Overview Presentation

GUIDING QUESTION

FOCUS Ask students to work with a partner for a think-pair-share activity. Have students think about the following question: What are some factors that could cause biodiversity to decrease? Ask each pair of students to discuss their thoughts. Call on each pair to share several of their ideas with the class.

A Sixth Mass Extinction? If current trends continue, the modern geologic era, known as the Quaternary period, may see the extinction of more than half of all species. Today, species loss seems to be accelerating as human population growth puts an increasing strain on habitats and wildlife. In 2005, scientists with the *Millennium Ecosystem Assessment* calculated that the current global extinction rate is 100 to 1000 times greater than the usual background rate. Moreover, they projected that the rate will be 10 times as high in future decades. These trends and predictions have caused some scientists to claim that we are in the middle of Earth's sixth mass extinction.

▶ ***Categorizing Risk*** To help track biodiversity trends, scientists classify at-risk species as either endangered or threatened. An **endangered species** is one that is at serious risk of extinction. A **threatened species,** or vulnerable species, is one that is likely to become endangered soon throughout all or part of its range. As of late 2009, there were 1321 species in the United States officially classified as "endangered" or "threatened." The International Union for the Conservation of Nature (IUCN) maintains the IUCN Red List of Threatened Species™, a global list of species facing high risk of extinction. The 2009 Red List reported that 21 percent (1142) of mammal species worldwide, including all remaining subspecies of tiger, are threatened or endangered.

▶ ***Tracking Decline*** Scientists at the World Wildlife Fund (WWF) and the United Nations Environment Programme (UNEP) developed a metric called the Living Planet Index to track species decline. This index summarizes population trends for a set number of terrestrial, freshwater, and marine species that are closely monitored and provide reliable data. As seen in **Figure 8,** between 1970 and 2005, the Living Planet Index fell by nearly 30 percent.

Reading Checkpoint *What is the difference between an endangered and a threatened species?*

BIG QUESTION

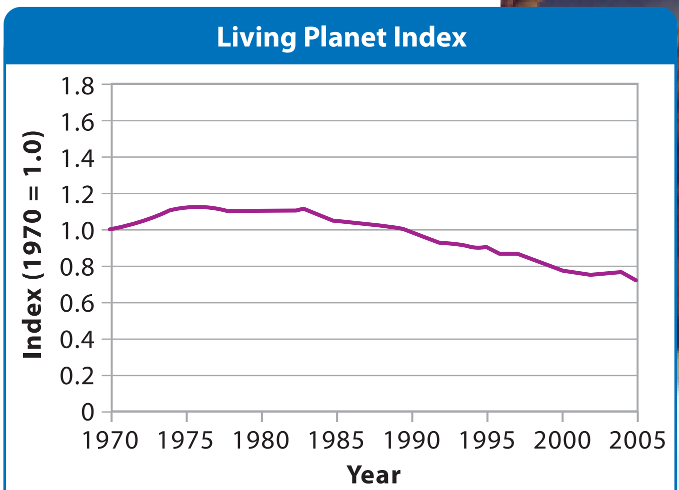
Why is it important to protect biodiversity?

Application Have students apply information about mass extinctions to develop a short slogan reminding others of the importance of protecting biodiversity.

ANSWERS

Reading Checkpoint An endangered species is at serious risk of extinction. A threatened species is likely to become endangered soon.

FIGURE 8 The Living Planet Index
Tigers are one of the more than 1600 vertebrate species whose population trends are summarized by the Living Planet Index. Biodiversity in 1970 is 1.0 on the graph. Between 1970 and 2005, the index fell by roughly 28%. The index for terrestrial species fell by 33%; for freshwater species, 35%; and for marine species, 14%.



Data from World Wide Fund for Nature, 2008. ***The Living Planet Report, 2008.*** Gland, Switzerland.

Causes of Biodiversity Loss

Habitat change and loss, invasive species, pollution, and overharvesting are the major causes of biodiversity loss. Climate change is also a factor and may become a greater one in the future.

Reasons for the decline of any given species are often complex and difficult to determine. Moreover, more than one factor is often to blame. Overall, scientists have identified four primary causes of population decline and species extinction: habitat change and loss, invasive species, pollution, and overharvesting. Many scientists think global climate change will become a greater factor in the future.

Habitat Change and Loss Because organisms are adapted to the places in which they live, any major change in their habitat is likely to make it less suitable. Clearing forests for logging or road building, for example, removes the food, shelter, and other resources that forest-dwelling organisms need to survive. Thus, organisms can be caught in "habitat islands," or patches of suitable habitat type surrounded by "seas" of unsuitable habitat. This pattern, shown in **Figure 9,** is called **habitat fragmentation.** The Sikhote-Alin Mountains, home of the Siberian tiger, is a habitat fragment. The tigers are trapped on the mountains, separated from other regions of suitable forested habitat by unsuitable populated areas.

Scientists have developed models that can predict the species diversity of a habitat fragment based on its size. In general, the larger the fragment, the more species it can support. Studies of oceanic islands have found that the number of species living on an island roughly doubles as island size increases tenfold. This is partly because large islands tend to have more habitats than smaller islands, providing suitable environments for a wider variety of arriving species. The pattern holds up for habitat fragments—the smaller the habitat island, the faster it tends to lose biodiversity.

Habitat change and loss is by far the greatest cause of biodiversity loss today. It is the primary source of population declines for 83% of threatened mammals and 85% of threatened birds, according to UNEP data. As one example, less than 1% of the prairies native to North America's Great Plains remain. The rest have been converted to farmland. As a result, grassland bird populations have declined by an estimated 82–90%. Of course, human-induced habitat change may benefit some species. Animals such as house sparrows, pigeons, gray squirrels, and cockroaches, for example, do very well in urban and suburban environments. However, the number of species that benefit are relatively few, and these species tend to be generalists that have the potential to become pests.

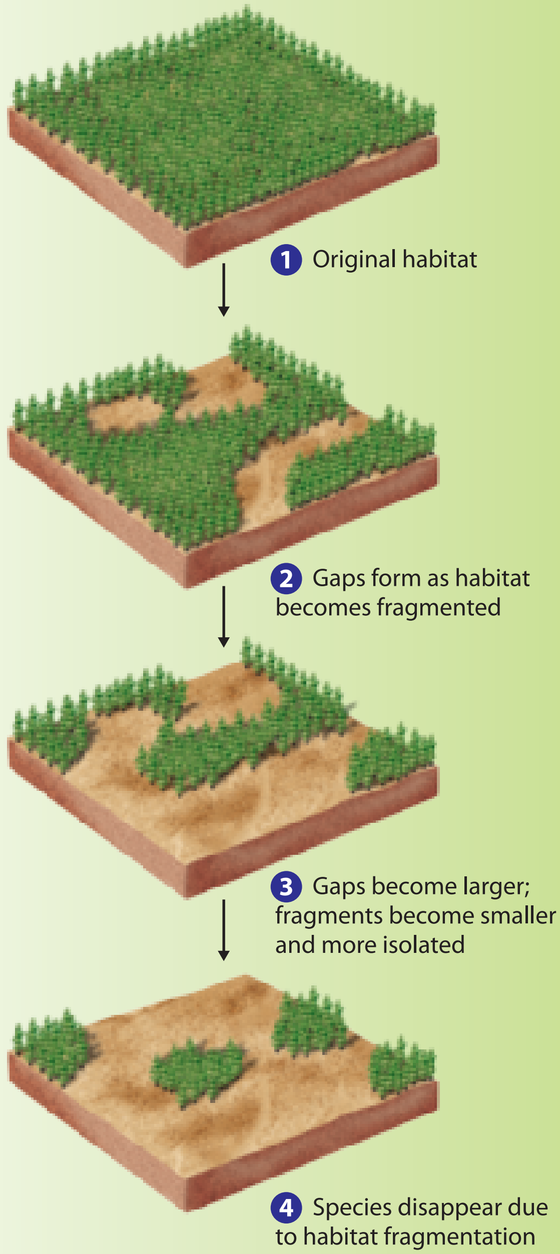


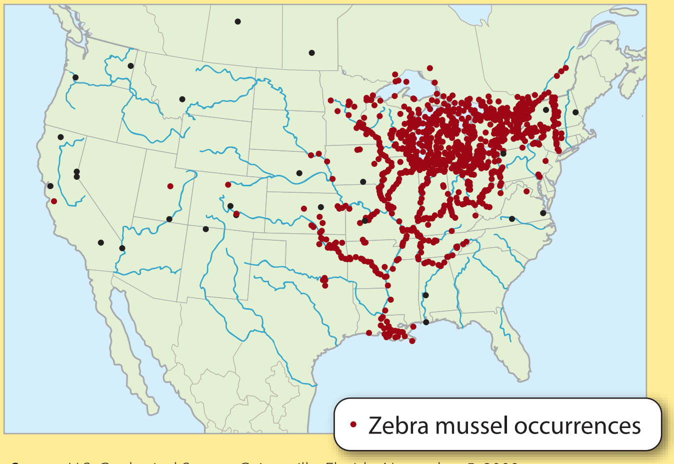
FIGURE 9 Habitat Loss Forest clearing, farming, road building, and other types of human land use and development can fragment natural habitats. As a habitat becomes fragmented, the number of species in the fragments decreases.

Map it

Invading Mussels

Zebra mussels were accidentally introduced to the Great Lakes from European and Asian cargo ships. The map at right shows the extent of the mussels' range as of late 2009.

1. **Apply Concepts** What qualities make zebra mussels invasive? (*Hint:* You may want to look back to the chapter *Evolution and Community Ecology*.)
2. **Interpret Maps** What is the relationship between the major rivers shown on the map (by blue lines) and the spread of zebra mussels?
3. **Infer** Notice the black dots on the map. Some of these locations appear to be inaccessible by inland waterways from the Great Lakes. How do you think zebra mussels got to these places?



Source: U.S. Geological Survey, Gainesville, Florida, November 5, 2009.

ANSWERS

Map It For answers to the Map It activity, see page A–10 at the back of the book.

Reading Checkpoint Invasive species often cause a decline in native biodiversity.

Invasive Species The introduction of non-native species to new environments can sometimes push native species toward extinction. Most organisms introduced to new areas do not survive long because the new area lacks certain conditions necessary for survival. However, some species can survive *too well*. Once released from the limiting factors of predation, parasitism, and competition, an introduced species may become invasive. Non-native species are considered invasive if their populations increase rapidly, spread, and displace native species. Invasive species, such as the zebra mussel, cause billions of dollars in economic damage each year. Very few, such as the honeybee, are beneficial.

Pollution Heavy metals, fertilizers, pesticides, and the toxic chemicals that pollute the air and water can poison people and wildlife. Although pollution is a substantial threat, it tends to be less significant than the damage caused by habitat loss or invasive species.

Overharvesting For most species, hunting or harvesting by humans does not pose a threat of extinction, but there are exceptions. Overharvesting occurs when humans hunt, fish, or harvest a species faster than it can replenish its population. Some species of fish, for example, are facing extinction because of overfishing. Likewise much of the Siberian tiger's population decline is due to overharvesting. Large, few in number, long-lived, and raising few young in its lifetime, the Siberian tiger is just the type of animal that is vulnerable to population reduction by hunting.

Reading Checkpoint *How do invasive species affect biodiversity?*

FIGURE 10 A Sticky Situation
Pollution, as from an oil spill, can poison humans and other living things. Here, a seabird is getting a bath to wash away oil leaked from a damaged ship in 2007 off the coast of England.

Hunting nearly drove Siberian tigers to extinction in the early twentieth century. Then after World War II, a decrease in hunting allowed the population to increase to about 250 individuals. The early 1990s, however, brought a boom in **poaching,** the illegal capture or killing of an organism. Organisms are often poached when their parts can be sold illegally. The parts from one tiger, for example, can be sold for about $15,000 in today's black market, which is a lot of money for poachers in poor regions.

Climate Change Habitat loss, invasive species, pollution, and overharvesting usually affect biodiversity only in certain places and at certain times. In contrast, recent changes to Earth's climate system are beginning to have *global* effects on biodiversity. Extreme weather events such as droughts increase stress on populations. Warming temperatures are causing organisms to move toward the poles and higher altitudes where the climate is cooler. Some species will be able to adapt, but others will not. In the Arctic, where warming has been greatest, polar bears are struggling as the ice they live and hunt on thins and melts (**Figure 11**). Unfortunately for the bears, there is nowhere colder for them to go and their future looks grim. Overall, scientists now predict that a 1.5–2.5°C global temperature increase could put 20–30 percent of the world's plants and animals at increased risk of extinction.

FIGURE 11 **On Thin Ice** The long-term survival of polar bears *(Ursus maritimus)* is threatened by climate change as Arctic warming melts the sea ice. The bears hunt seals from the icy surface. Less ice means they have to swim farther for food, sometimes drowning in the process.

ANSWERS

Lesson 2 Assessment

1. The Living Planet Index summarizes population trends for a set number of species that are closely monitored. It shows a recent decline in biodiversity.
2. Habitat change and loss, pollution, overharvesting, invasive species, and climate change; habitat change has the greatest overall effect; climate change can affect global, not just local, biodiversity.
3. Answers will vary.

LESSON 2 Assessment

1. **Explain** What is the Living Planet Index and what does it suggest about current biodiversity trends?
2. **Apply Concepts** What are the major factors affecting biodiversity today? Which one currently has the greatest overall effect? How is climate change different from the other factors?
3. **THINK IT *THROUGH*** Suppose someone tells you that human development increases biodiversity. When a forest is fragmented, he or she argues, new habitats, such as grassy lots and gardens, may be introduced to an area and allow additional species to live there. How would you respond to this claim? Do you agree? Explain your answer.

LESSON 3

Protecting Biodiversity

Guiding Question: How can we protect and preserve biodiversity?

Knowledge and Skills

- Explain legal actions nations can take to protect biodiversity.
- Explain the goal of Species Survival Plans.
- Describe three strategies for managing whole ecosystems and habitats.

Reading Strategy and Vocabulary

Reading Strategy Before you read, set up a T-chart. Label the left column "Ways to Protect Biodiversity" and the right column "Details." As you read, fill in both columns. You may choose to use the blue headings to fill in the left column.

Vocabulary Endangered Species Act (ESA), captive breeding, Species Survival Plan (SSP), biodiversity hotspot, endemic

TODAY, MORE AND MORE SCIENTISTS and citizens see a need to do something about the loss of biodiversity. In his 1994 autobiography, *Naturalist*, E. O. Wilson writes: "When the [20th] century began, people still thought of the planet as infinite in its bounty. The highest mountains were still unclimbed, the ocean depths never visited, and vast wildernesses stretched across the equatorial continents." But, since then, extinction rates have increased, and what was once seemingly endless wilderness is now threatened. So, Wilson writes, "Troubled by what we have wrought, we have begun to turn in our role from local conqueror to global steward." Is Wilson right? Are we changing roles from conqueror to steward? And are we doing enough to protect remaining biodiversity?

Legal Efforts

Nations can pass laws and sign international treaties that protect biodiversity.

Biodiversity can be protected by law. In the United States, the major law that protects biodiversity is the **Endangered Species Act (ESA).** Passed in 1973, the ESA has three major parts. First, it forbids the government and private citizens from harming listed endangered and threatened species or their habitats. Harmful actions could be direct, such as cutting down protected tree species, or indirect, like funding such a project. Second, the ESA forbids trade in products made from species that are on the list. Finally, it requires the U.S. Fish and Wildlife Service to maintain the official list of endangered and threatened organisms, and to develop recovery plans for each protected species. The goal of the law is to prevent extinctions by protecting at-risk species from natural or artificial threats, such as pollution, predation, disease, and habitat destruction. The hope is that with protection, declining populations can stabilize and eventually recover.

Reading Checkpoint *What does the Endangered Species Act do for protected species?*

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7.3 LESSON PLAN PREVIEW

Differentiated Instruction Struggling students organize and compare legal efforts to protect biodiversity.

Real World Students discuss whether cloning can save endangered species.

Inquiry Students research and create a poster on one of Earth's biodiversity hotspots.

7.3 RESOURCES

In Your Neighborhood Activity, *Endangered Species* • Bellringer Video, *Belize's Safe Haven for Animals* • Real Data Online • Real Data Math Worksheet • Lesson 7.3 Worksheets • Lesson 7.3 Assessment • Chapter 7 Overview Presentation

FOCUS Watch the ABC News video **Belize's Safe Haven for Animals,** which describes one woman's efforts to protect animals in Belize. Use the video to launch a discussion about actions that can help protect biodiversity.

FIGURE 12 Protection Under Law (a) The peregrine falcon *(Falco peregrinus)* owes its recovery to careful management under the ESA. **(b)** ESA protection for the northern spotted owl *(Strix occidentalis caurina)* caused some controversy in the Pacific Northwest when loggers lost their jobs.

Benefits and Costs of the ESA The ESA has had a number of notable successes. For example, the peregrine falcon **(Figure 12a),** brown pelican, bald eagle, and other birds affected by the pesticide DDT are no longer listed as endangered. Other species, such as the red-cockaded woodpecker, are still endangered, but have stopped declining thanks to careful management under the ESA. In fact, roughly 40 percent of once-declining populations in the United States are now stable.

Polls repeatedly show that most Americans support the idea of protecting endangered species. However, some feel that species preservation under the ESA comes at too high a price. In the 1990s, part of the species recovery plan for the northern spotted owl **(Figure 12b)** in the Pacific Northwest, for example, protected large areas of old-growth forest. During the decline in timber harvesting that followed, many loggers lost their jobs. In addition, some landowners worry that use of their private land could be restricted if threatened or endangered species are found on it. Supporters, however, point out that parts of the ESA promote cooperation and trade-offs with landowners and developers.

International Cooperation At the international level, the United Nations has facilitated several treaties to protect biodiversity. A treaty is an agreement under international law. When nations ratify a treaty, they promise to uphold the laws that are described. One important biodiversity treaty is the 1975 Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). CITES protects endangered species by banning the international transport of their body parts. When enforced by the 175 member nations, CITES can protect tigers and other rare species whose body parts are traded internationally.

In 1992, leaders of many nations met in Rio de Janeiro, Brazil, and agreed to the Convention on Biological Diversity, sometimes called the biodiversity treaty. The treaty has three goals: to conserve biodiversity, to use biodiversity in a sustainable manner, and to ensure the fair distribution of biodiversity's benefits. The treaty has already had many accomplishments. It has helped increase global markets for "shade-grown" coffee and other crops grown without removing forests, for example. As of 2009, close to 200 nations have joined the Convention on Biological Diversity. The United States has signed the treaty, but has not ratified it, meaning that the treaty is not yet enforced by U.S. law.

BIG QUESTION

Why is it important to protect biodiversity?

Explanation Have students work in teams to form opinions on the importance of international cooperation in the protection of biodiversity. Have each team write a statement summarizing their opinion, and have team members verbally support and justify their team's opinion using information from the chapter.

ANSWERS

Reading Checkpoint The ESA forbids people and governments from harming listed species, and selling anything made from listed species. It also requires the U.S. Fish and Wildlife Service to maintain the list and come up with recovery plans for each protected species.

Make A Difference Answers will vary.

your world • your turn •

MAKE A DIFFERENCE

Do you think the United States should ratify the biodiversity treaty? Write a letter to your state or federal legislator explaining why you think it is or is not important that the United States enforce the regulations of the treaty.

Single-Species Approaches

Species Survival Plans manage, protect, and reintroduce threatened and endangered species.

Conservation biologists use field data, lab data, theory, and experiments to study the effects of people on other organisms. In protecting biodiversity, conservation programs can target specific, single species, or can try to protect whole habitats and ecosystems. Captive breeding and cloning are examples of single-species approaches.

ANSWERS

Real Data

1. By about 400%
2. About 500
3. They are offspring of the captive tamarins that were reintroduced.
4. Answers will vary.

Reading Checkpoint An endemic species is one that is found only in one particular place.

Captive Breeding Programs In the effort to save threatened and endangered species, zoos and botanical gardens have become centers for captive breeding. **Captive breeding** is the process of breeding and raising organisms in controlled conditions. In modern zoos and aquariums, captive breeding is part of an overall program to protect the species called a **Species Survival Plan (SSP).**

Golden Lion Tamarin

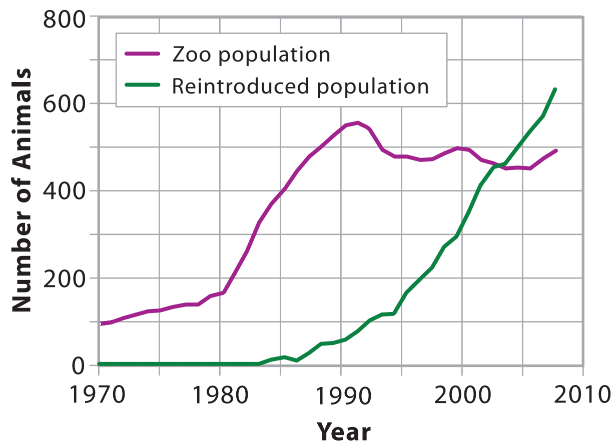
Real Data

Golden Lion Tamarin

Species Survival Plans, or SSPs, are efforts to protect and manage captive populations of specific organisms. These plans are coordinated by zoos and aquariums with the ultimate goal of reintroducing healthy individuals to the wild. Since the early 1980s, Dr. Jonathan Ballou at the Smithsonian Institution's National Zoo in Washington, D.C., has been tracking and managing the captive population of golden lion tamarins around the world. Some of his data are shown at right.

1. **Calculate** By approximately what percent has the zoo population of tamarins in this SSP increased since 1970?
2. **Analyze Data** Reintroduction typically begins once a captive population has reached a certain "target size." Based on the graph, what is the approximate target captive population size for the golden lion tamarin?
3. **Infer** According to Dr. Ballou's data, 153 golden lion tamarins have been reintroduced to the wild from captivity. However, according to the graph, the reintroduced population includes about 650 individuals. Where did the other 497 tamarins come from?

Recovery and Reintroduction of the Golden Lion Tamarin



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

4. **Form an Opinion** Do you think it is ever okay to remove animals from the wild and bring them into captivity? Why or why not?

In North America, the Association of Zoos and Aquariums (AZA) currently oversees SSPs for more than 180 species. Captive breeding as part of an SSP is carefully managed to ensure the greatest possible genetic diversity. One goal of SSPs is for captive-bred organisms to be reintroduced into the wild. SSPs also involve education, outreach, and research.

One example of a successful SSP is the program to save the golden lion tamarin *(Leontopithecus rosalia)*. Golden lion tamarins are primates native to the coastal forests of Brazil. By the early 1970s, habitat fragmentation had caused a dramatic population decline—only 200 or so were left in the wild. The SSP for golden lion tamarins started with just 91 individuals in 26 zoos. As of 2007, there were nearly 500 golden lion tamarins in 145 participating zoos worldwide. And best of all, more than 150 tamarins cared for in captivity have been reintroduced to the wild.

Cloning The newest idea for saving species from extinction is to make more individuals through cloning. In this technique, DNA from an endangered species is inserted into a cultured egg cell that has had its nucleus removed. The egg is then implanted into a closely related species that can act as a surrogate mother. Even if cloning can succeed from a technical standpoint, most biologists agree that cloning won't really help prevent biodiversity loss. Without ample habitat and protection in the wild, most scientists think having cloned animals in a zoo does little good.

Ecosystem and Habitat Approaches

Strategies that manage whole ecosystems and habitats, such as the hotspot approach, conservation concessions, and wildlife corridors, protect many species at once.

Most laws, including the Endangered Species Act, do not specifically provide protection for whole habitats and ecosystems, only individual species. However, many conservation biologists recognize the need to move beyond single-species approaches.

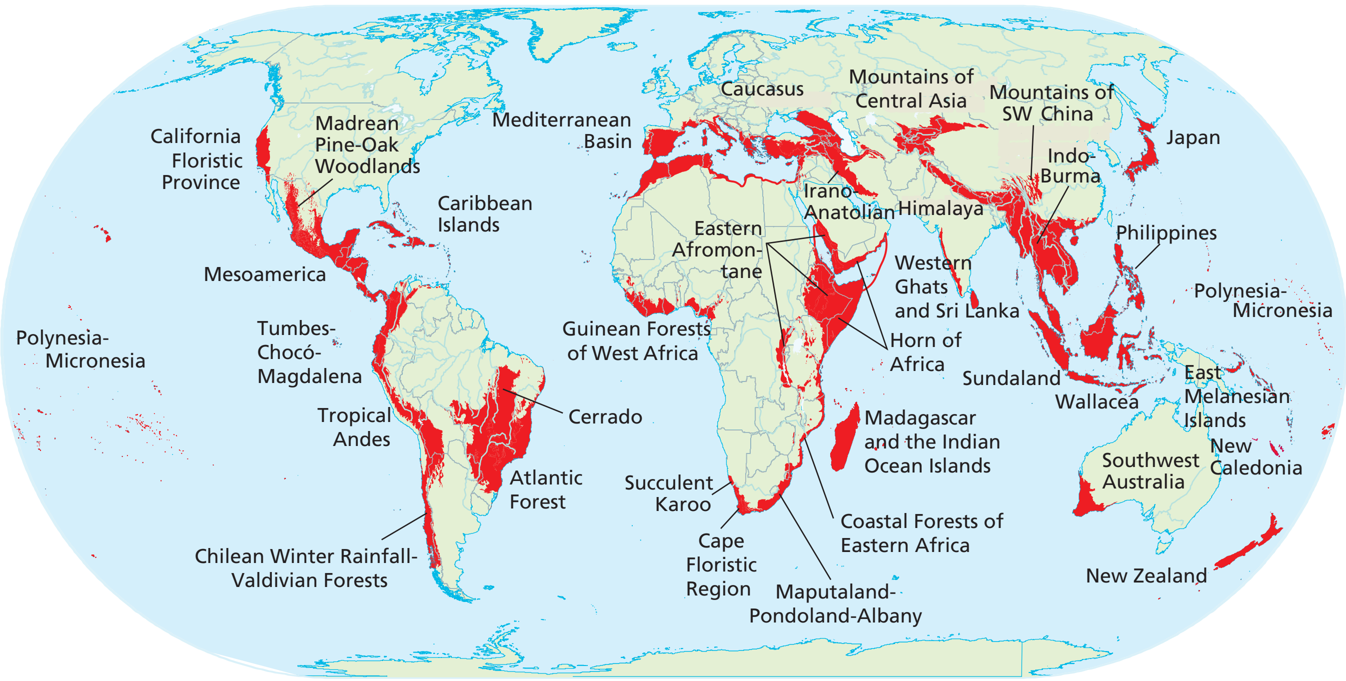
Biodiversity Hotspots One effort oriented around geographic regions, rather than single species, is the mapping of biodiversity hotspots. A **biodiversity hotspot** is an area that both supports an especially high number of endemic species and is rapidly losing biodiversity. A species is **endemic** to an area if it is found nowhere else in the world. To qualify as a hotspot, a location must harbor at least 1500 endemic plant species, or 0.5% of the world total. In addition, a hotspot must have already lost 70% of its habitat as a result of human actions and be in danger of losing more. Hotspots are seen as areas critical to global biodiversity.

Reading Checkpoint *What is an endemic species?*

FIGURE 13 Endemic Species This enormous tree is a coastal redwood *(Sequoia sempervirens)*, a species found only in a thin strip of land from central California to Oregon. It is one of the species endemic to the biodiversity hotspot known as the California Floristic Province.

FIGURE 14 Biodiversity Hotspots Some areas of the world possess exceptionally high numbers of species found nowhere else. Many conservation biologists have supported prioritizing habitat preservation in these areas, called biodiversity hotspots. Shown in red are the 34 biodiversity hotspots mapped by Conservation International.

The nonprofit group Conservation International maintains a list of 34 biodiversity hotspots, shown in **Figure 14.** Together, these areas once covered 15.7% of the planet's land surface. Today, however, they cover only 2.3%. This small amount of land is the exclusive home for 50% of the world's plant species and 42% of all terrestrial vertebrate species. The hotspot concept helps conservation biologists focus on these areas, where the greatest number of unique species can be protected with the least amount of effort.



Adapted from *Hotspot map,* Conservation International, 2005.

Economic Approaches Many of today's conservation efforts attempt to protect not only land and wildlife, but the economic interests of the local people as well. Wisconsin-based Community Conservation, for example, has set up a number of community-based conservation projects in the small Central American nation of Belize. These projects not only protect wildlife, but also bring in money from researchers and ecotourists.

A more direct economic approach is the *debt-for-nature swap.* Here, a conservation organization raises money and offers to pay off a portion of a developing nation's international debt in exchange for a promise by the nation to set aside reserves, fund environmental education, and better manage protected areas.

A newer economic strategy that Conservation International has pioneered is called the *conservation concession.* Governments often sell concessions, or rights, to corporations allowing them to extract resources. A nation can, for example, earn money by selling the right to log its forests. Conservation International has started paying countries for the right to conserve its resources, not extract them. The South American nation of Suriname, which has extensive areas of untouched rain forest, entered into such an agreement. As a result, Suriname has made about $15 million and logging in the rain forest has been significantly reduced.

Reading Checkpoint *How do conservation concessions work?*

ANSWERS

Reading Checkpoint Conservation groups pay nations to conserve resources, rather than extract and sell them.

FIGURE 15 Safe Passage The southern cassowary (left) is a large flightless bird closely related to the emu and ostrich. Only 1200–1500 individuals remain in Australia. Conservation biologists hope that when completed, the corridor (right) will enable isolated cassowary populations to interbreed. Above, volunteers are planting trees that will form part of the corridor.

Wildlife Corridors Recall that population sizes often decline when habitat is fragmented. One way to increase fragment size is to establish *wildlife corridors* that connect habitat fragments. A major benefit of wildlife corridors is that they enable once-isolated populations of organisms to interbreed, thus increasing genetic diversity.

There are currently several corridor initiatives at work in Southeast Asia to help rejoin fragments of tiger habitat. The most ambitious is a proposal made in 2008, by the Wildlife Conservation Society and the Panthera Foundation. They hope to someday establish an 8000-km (5000-mi)-long corridor across eight southeast Asian countries. The Australian Rainforest Foundation is in the midst of a similar project called "Operation Big Bird." The foundation is building a 250-km (150-mi)-long corridor of rainforest habitat for the endangered southern cassowary (*Casuarius casuarius*). With luck, the corridor will help the declining population of this unusual "big bird" to recover.

ANSWERS

Lesson 3 Assessment

1. Benefits: protects endangered species and prevents extinctions; costs: creates barriers to land development and can cost jobs
2. The captive population has increased and more than 150 golden lion tamarins have been reintroduced to the wild.
3. Each deals with protection of whole habitats and ecosystems.
4. Answers will vary.

LESSON 3 Assessment

1. **Explain** What are the major benefits and costs of the Endangered Species Act?
2. **Apply Concepts** In what ways has the golden lion tamarin SSP been successful?
3. **Compare** What do the hotspot mapping project, conservation concession programs, and wildlife corridors have in common?
4. Explore the **BIG**QUESTION What are some of the advantages to focusing on the conservation of a single species versus trying to conserve ecosystems or habitats? What might be some of the disadvantages? Which do you think is the better approach, or should we use both?