The Papahānaumokuākea Marine National Monument, designated in 2006, surrounds the northwestern Hawaiian Islands and protects more than 7,000 species of marine organisms, including these Hawaiian squirrel fish (*Sargocentron xantherythrum*). (James D. Watt/Oceanstock/SeaPics.com) chapter 18

Conservation of Biodiversity

Modern Conservation Legacies

The biodiversity of the world is currently declining at such a rapid rate that many scientists have declared that we are in the midst of a sixth mass extinction. There are many causes of this decline, but all are related to human activities ranging from habitat destruction to overharvesting plant and animal populations. In response to this crisis, there is growing interest in conserving biodiversity by setting aside areas that are protected from many human activities.

The conservation of biodiversity has a long history. The United States, for example, has been protecting habitats as national parks, national monuments, national forests, and wilderness areas for more than a century. Yellowstone National Park was the first national park in the United States, designated in 1872 by President Ulysses Grant. During the presidency of Theodore Roosevelt (1901–1909), nearly 93 million hectares (230 million acres) received federal protection. This included the creation of more than a hundred national forests, although much of this land was set aside to ensure a future supply of trees for lumber and therefore lacked complete protection.

Efforts to protect marine habitats are relatively recent.

In contrast to the long history of protecting terrestrial habitats, efforts to protect marine habitats are relatively recent. One of the most expansive efforts in the United States was made during the administration of George W. Bush. From 2006 to 2009, President Bush designated a total of 95 million hectares (215 million acres) of marine habitats as protected around the northwestern Hawaiian Islands and other U.S. Pacific islands. In the northwestern Hawaiian Islands, 36 million hectares (90 million acres) of these marine habitats were set aside as the Papahānaumokuākea Marine National Monument. This protected region is immense, covering an area about the size of California.

The marine ecosystem that surrounds the Hawaiian Islands contains a great deal of biodiversity—more than 7,000 marine species, approximately one-fourth of which are found nowhere else in the world. Unfortunately, in recent decades human activities have caused a decline in this diversity. The human causes of declining diversity are wide ranging. Although Hawaii has only 1.3 million residents, 7 million tourists visit each year. Individual anglers and commercial fishing operations have exploited marine life, including coral and fish. In addition to this exploitation, there are thousands of kilograms of old fishing equipment lying at the bottom of the ocean that sometimes wash up on shore, entangling wildlife in old fishing lines. Invasive species of algae also dominate some areas.

The Papahānaumokuākea monument presents an opportunity for improving the Hawaiian marine environment. As a national monument, the area is protected from fishing, harvesting of coral, and the extraction of fossil fuels. Large amounts of solid waste debris are being removed from the shorelines and coral reefs, and efforts are under way to clean out much of the invasive algae. It is expected that the biodiversity of the area will quickly respond to these efforts. As the populations of organisms increase in the protected areas, individuals will disperse and add to the populations in the larger surrounding area. In this way, the protected area can serve as a constant supply of individuals to help neighboring areas maintain their diversity of species.

In the United States and the rest of the world, conserving the biodiversity of marine areas by creating marine reserves is a relatively new activity for governments, but the idea is gaining ground. In the Galápagos Islands, where Charles Darwin studied the evolution of finches, the nation of Ecuador recently designated a marine reserve that extends 64 km (40 miles) into the ocean from the islands and allows only limited fishing. Marine reserves have also been designated by Russia, the United Kingdom, Australia, Canada, and Belize.

Efforts to protect critical wildlife habitats continue today. For example, in 2009 the Obama administration set aside more than 484,000 km^2 (187,000 square miles) of Alaska coastline and waters as critical habitat for polar bears. Although this does not prevent activities such as gas and oil drilling, it does mean that potential impacts on polar bears must now be considered when such activities are proposed in this area. As more countries develop marine reserves, we have to make sure these areas are large enough to allow long-term protection of local species and we must consider how each new reserve is positioned relative to other reserves so that individuals are able to move among them. Furthermore, countries must decide what human activities will be allowed in each reserve, perhaps protecting a core area and allowing tourism, fishing, or extraction of fossil fuels to occur in more distant areas of the reserve. These are exciting times that demonstrate that there is a great potential for conserving biodiversity in the twenty-first century.

Sources:

P. Thomas, President Bush to add marine reserves; not all are applauding, *Los Angeles Times*, January 6, 2009. http://latimesblogs.latimes.com/outposts/2009/01/news-flash-pres.html; U.S. government heads for row with big business after Obama sets aside land in Alaska for polar bear sanctuary, *Daily Mail*, November 25, 2010. http://www.dailymail.co.uk/news/article-1333008/Obama-sets-aside-land-Alaska-polar-bear-sanctuary.html.

Preserving habitats is one important way to protect against declines in the world's biodiversity. In this chapter, we will examine declines in biodiversity at multiple levels including declines in the genetic diversity of wild plants and animals, declines in the genetic diversity of domesticated plants and animals, and declines in the species of large taxonomic groups. We will also investigate the major causes of these declines, which include habitat loss, overharvesting, and the introduction of species from other regions of the world. To help curb the loss of biodiversity, we have a number of laws and international agreements that are in effect. Approaching these efforts with an understanding of the concepts of metapopulations, island biogeography, and biosphere reserves can help us succeed in protecting large ecosystems.

module

59

The Sixth Mass Extinction

In Chapter 5, we noted that the world has experienced five major extinctions during the past 500 million years. Many scientists have suggested that we may currently be in the midst of a sixth mass extinction event. In the most recent assessment made in 2014, scientists estimate that the world is currently experiencing approximately 1,000 species extinctions per year. This sixth mass extinction is unique because it is happening over a relatively short period of time and is the first mass extinction to occur since humans have been present on Earth.

In this module, we will examine the declines in biodiversity of Earth at various levels of complexity including genetic diversity, species diversity, and ecosystem function. In each case, we will examine the roles that humans have played in the decline of biodiversity.

Learning Objectives

After reading this module you should be able to

- explain the global decline in the genetic diversity of wild species.
- discuss the global decline in the genetic diversity of domesticated species.
- identify the patterns of global decline in species diversity.
- explain the values of ecosystems and the global declines in ecosystem function.

We are experiencing global declines in the genetic diversity of wild species

At the lowest level of complexity, environmental scientists are concerned about conserving genetic diversity. Populations with low genetic diversity are not well suited to surviving environmental change and they are prone to inbreeding depression, as we discussed in Chapter 6. Inbreeding depression by parents that each carry a harmful recessive mutation causes some of their offspring to receive two copies of the harmful mutation and, as a result, causes the offspring to have a poor chance of survival and later reproduction. High genetic diversity ensures that a wider range of genotypes is present, which reduces the probability that an offspring will receive the same harmful mutation from both parents. In addition, high genetic diversity improves the probability of surviving future change in the environment. This happens because high genetic diversity produces a wide range of phenotypes that survive and reproduce under different environmental conditions.

Some declines in genetic diversity have natural causes. Cheetahs, for example, possess very low genetic diversity. Researchers have determined that this condition is the result of a population bottleneck that occurred approximately 10,000 years ago (see Figure 15.10). Other declines in genetic diversity have human causes. For example, we discussed in Chapter 5 that the Florida panther once roamed throughout the southeastern United States (FIGURE 59.1). Because of hunting and habitat destruction, the population of the Florida panther shrank to only a small group in south Florida and this led to inbreeding. This inbreeding caused a number of harmful defects that caused the population to decline even further. After scientists released 8 panthers from Texas into Florida to add genetic diversity, the Florida panther population increased from 20 to nearly 100 individuals.

FIGURE 59.1 Declines in genetic diversity. The Florida panther was reduced to such a small population that it suffered severe effects of inbreeding. In recent years the introduction of new genotypes from a Texas population has allowed the Florida panther to rebound. *(Thomas & Pat Leeson)*

We are also experiencing global declines in the genetic diversity of domesticated species

Although declining genetic variation of plants and animals in the wild is of great concern to scientists, there are also major concerns about declining genetic variation in the domesticated species of crops and livestock on which humans depend. The United Nations notes that the majority of livestock species comes from seven species of mammals (donkeys, buffalo, cattle, goats, horses, pigs, and sheep) and four species of birds (chickens, ducks, geese, and turkeys). In different parts of the world, these species have been bred by humans for a variety of characteristics including adaptations that allow them to survive local climates. For example, humans have bred for a tremendous diversity of traits in cattle, as illustrated in FIGURE 59.2. This wide variety of adaptations, which is produced by a great deal of genetic variation, could be used for

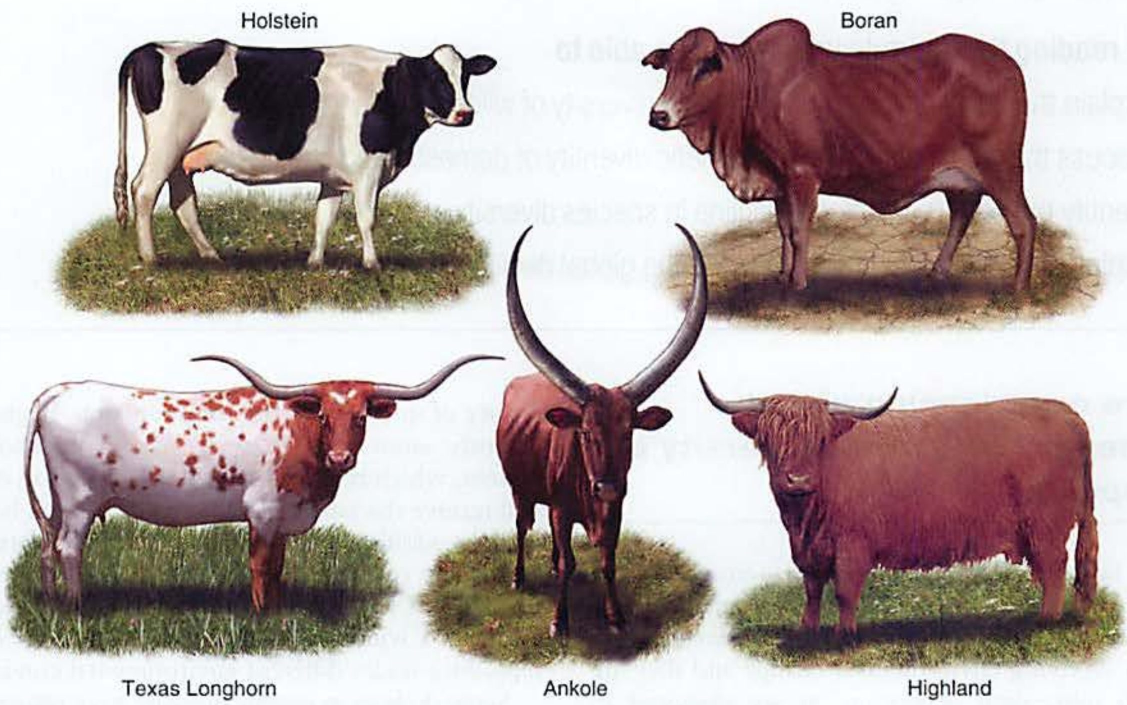

FIGURE 59.2 The genetic diversity of livestock. Over thousands of years, humans have selected for numerous breeds of domesticated animals to thrive in local climatic conditions and to resist diseases common in their local environments. Modern breeding, which focuses on productivity, has caused the decline or extinction of many of these animal breeds.

FIGURE 59.3 A global seed bank. The Svalbard Global Seed Vault in northern Norway is an international storage area for many varieties of crop seeds from throughout the world. *(Jim Richardson/National Geographic Society/Corbis)*

adapting to changing environmental conditions in the future or resisting new diseases. Unfortunately, livestock producers have concentrated their efforts on the breeds that are most productive and much of this genetic variation is being lost. In Europe, for example, half of the breeds of livestock that existed in 1900 are now extinct. Of those that remain, 43 percent are currently at serious risk of extinction. Of the 200 breeds of domesticated animals that have been evaluated in North America, 80 percent of these breeds are either declining or are already facing extinction.

A similar story exists for crop plants. A century ago, most of the crops that humans consumed were composed of hundreds or thousands of unique genetic varieties. Each variety grew well under specific environmental conditions and was usually resistant to local pests. In addition, each variety often had its own unique flavor. As we saw in Chapter 11, the green revolution in agriculture focused on techniques that increased productivity. Farmers planted fewer varieties, concentrating on those with higher yields. Fertilizers and irrigation helped humans control many of the abiotic conditions, allowing fewer but higher-yielding varieties to be grown across large regions of the world. For example, at the turn of the twentieth century, farmers grew approximately 8,000 varieties of apples. Today, that number has been reduced to about 100, and considerably fewer are available in your local grocery store.

Planting only a few varieties leaves us open to crop loss if the abiotic or biotic environment changes. For example, in the 1970s, a fungus spread through cornfields of the southern United States and killed half the crop. Although the fungus was uncommon, the high-yielding variety of corn that most farmers planted turned out to be susceptible to it. Following this crisis, scientists modified this high-yielding corn by adding a gene from a variety that is resistant to the fungus. Had the resistant variety not been preserved, this gene would not have been available.

The nations of the world have recognized the problem of declining seed diversity and have responded by storing seed varieties in specially designed warehouses to preserve genetic diversity. In fact, there are currently more than 1,400 such storage facilities around the world. However, many of these facilities are at risk from war and natural disasters. In the past decade, nations and philanthropists have funded an international storage facility known as the Svalbard Global Seed Vault (FIGURE 59.3). This facility consists of a tunnel built into the side of a frozen mountain on an island in the Arctic region of northern Norway. It was designed to resist a wide range of possible calamities, including natural disasters and global warming. Should the environment change in future years, either in terms of abiotic conditions or because of emergent diseases, the seed bank will be available to help scientists address the challenge. The Svalbard facility opened in 2008 with a capacity of 14.5 million seed varieties. As of 2013, more than 700,000 seed samples had been sent to Svalbard for long-term storage.

Species diversity has declined around the world

Extinction occurs when the last member of a species dies. These major extinction events are characterized as a loss of at least 75 percent of all species within a period of 2 million years. Scientists estimate that as a result of

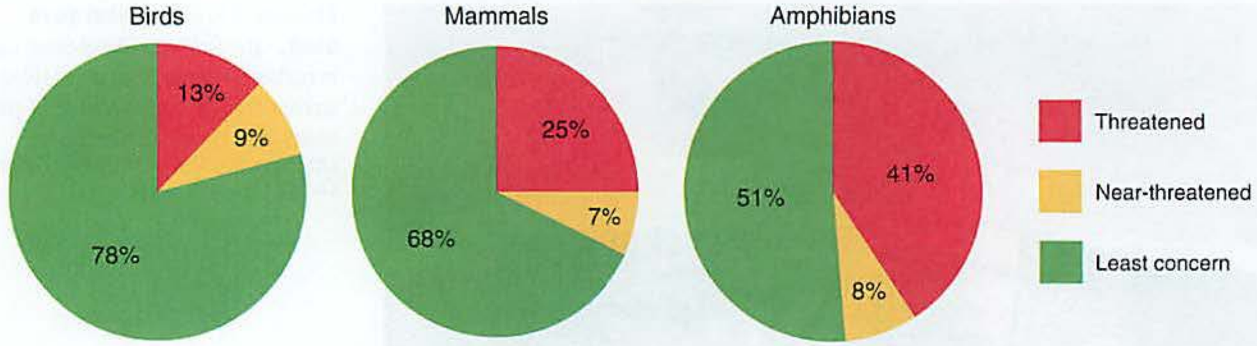

FIGURE 59.4 The decline of birds, mammals, and amphibians. Based on those species for which scientists have reliable data, 21 percent of birds, 32 percent of mammals, and 49 percent of amphibians are currently classified as threatened or near-threatened with extinction. *(After International Union for Conservation of Nature, 2009)*

these multiple mass extinctions and many minor extinctions, nearly 99 percent of the 4 billion species that have existed on Earth have gone extinct. However, because each of these mass extinction events has been followed by high rates of speciation that produced new species, we still have millions of species on Earth.

One way to assess the current extinction rate is by comparing the rate of extinction for groups of organisms, such as mammals, for which we have an excellent fossil record. Using this fossil record, we can compare the rate of species extinctions during the past 500 years to previous 500-year intervals. When we do this, we find that the rate of extinction during the past 500 years is higher than in previous 500-year periods. Indeed, the United Nations Convention on Biological Diversity estimates that the rate of extinction has been 1,000 times higher during the past 50 years than at any other time in human history and rivals the rates observed during the mass extinction event that eliminated the dinosaurs 65 million years ago.

To understand the current loss of species around the world, we can look at how particular groups of species are declining. When considering the status of a species, we use one of five categories defined by the International Union for Conservation of Nature (IUCN). Data-deficient species have no reliable data to assess their status; they may be increasing, decreasing, or stable. Species for which we have reliable data are placed in one of four categories. Extinct species are those that were known to exist as recently as the year 1500 but no longer exist today. The IUCN defines **threatened species** as those that have a high risk of extinction in the future and **near-threatened species** are very likely to become threatened in the future. **Least concern species** are widespread and abundant. These categories provide a mechanism for comparing the status of different groups of species.

Threatened species According to the International Union for Conservation of Nature (IUCN), species that have a high risk of extinction in the future.

Near-threatened species Species that are very likely to become threatened in the future.

Least concern species Species that are widespread and abundant.

Evaluating the status of different plant and animal groups presents several challenges. Many species fall under the category of data-deficient. At the same time, we are still discovering many new species, particularly in remote areas of the world. Since the number of species known to science constantly increases, it is not possible to evaluate every species and our estimates of what fraction of species are declining will constantly change. Finally, the work is expensive. Making an assessment for even one group of species, such as birds or mammals, requires thousands of scientists and millions of dollars.

Of the estimated 10 million species that currently live on Earth, ranging from bacteria to whales, only about 50,000 have been assessed to determine whether their populations are increasing, stable, or declining. Across all groups of organisms that have been assessed, nearly one-third are threatened with extinction. Given that some of the best data are for birds, mammals, and amphibians, we will examine these groups in more detail. FIGURE 59.4 shows the data for those species that are not yet extinct.

Since the year 1500, nearly 10,000 bird species have existed and 130 have become extinct. Today, 22 percent are threatened or near-threatened. Among the 800 species of birds living in the United States, nearly one-third are experiencing declining populations. These include 40 percent of bird species that live in grasslands and 30 percent of bird species that live in arid regions. Multiple threats, including reduced habitat and rising sea levels, have caused a growing concern for all species of birds that live on coastlines or on islands.

A similar pattern exists for mammals. Of the nearly 5,500 species of mammals known to have existed after 1500, 77 are extinct. Among the approximately 4,600 species for which there are reliable data, 25 percent are threatened and 32 percent are either threatened or near-threatened. This means that more than 1,400 species of mammals may be at risk of extinction.

Amphibians are experiencing the greatest global declines. Of the more than 6,300 species of amphibians, 34 species are extinct. However, a recent assessment of amphibian populations suggests that the number of extinctions may accelerate in the coming decades. Among the approximately 4,700 species for which reliable data exist, 49 percent are either threatened or near-threatened. This means that nearly 2,300 species of amphibians are declining around the world.

Many other groups of organisms are also experiencing large declines, but complete assessments have not yet been conducted because of the time and money required for each assessment. However, from the sample of species that have been assessed in each group, we see an emerging picture that is far from positive. For example, from this sample, approximately one-third of all reptiles, fish, and invertebrates are threatened with extinction. Similarly, one-fourth of plant species are threatened. These results suggest that when the assessments are complete, the news will most likely not be good.

Ecosystem values and the global declines in ecosystem function

Given that we rely on a relatively small number of the millions of species on Earth for our essential needs, why should we care about the millions of other species that live in various ecosystems? To understand the value of ecosystems, we can consider both *intrinsic values* and *instrumental values*.

Many people believe that ecosystems have **intrinsic value**—that is, that ecosystems are valuable independent of any benefit to humans. These beliefs may grow out of religious or philosophical convictions. People who believe that ecosystems are inherently valuable may argue that we have a moral obligation to preserve them. They may equate the obligation of protecting ecosystems with our responsibility toward people or animals that might need our help to survive. People who argue that ecosystems are valuable independent of any benefit to humans generally believe that environmental policy and the protection of ecosystems should be driven by this intrinsic value.

An ecosystem may also have **instrumental value,** meaning that it has worth as an instrument or tool that can be used to accomplish a goal. Instrumental values, which include the value of items such as crops, lumber, and pharmaceutical drugs, can be thought of in terms of how much economic benefit a species bestows. As noted in Chapter 1, we often refer to these instrumental values as ecosystem services. When calculating the instrumental value of various ecosystem services, we can consider five categories: *provisions, regulating services, support systems, resilience,* and *cultural services.*

Provisions

Goods produced by ecosystems that humans can use directly are called **provisions.** Examples include lumber, food crops, medicinal plants, natural rubber, and furs. Of the top 150 prescription drugs sold in the United States, about 70 percent come from natural sources. For example, Taxol, a potent anticancer drug, was originally discovered in the bark of the Pacific yew (*Taxus brevifolia*), a rare tree that grows in forests of the Pacific Northwest (**FIGURE 59.5**). Once approved by

FIGURE 59.5 Provisions. Scientists discovered that the bark of the Pacific yew contains a chemical that has anticancer properties. *(Inga Spence/Science Source)*

Intrinsic value Value independent of any benefit to humans.

Instrumental value Worth as an instrument or a tool that can be used to accomplish a goal.

Provision A good that humans can use directly.

FIGURE 59.6 Regulating services. Tropical rainforests play a major role in regulating the amount of carbon in the atmosphere. *(John Pontier/Earth Scenes/Animals Animals)*

the FDA, the synthetic version of this single drug has had annual sales of over $1.5 billion. There is no way to estimate the potential value of natural pharmaceuticals that have yet to be discovered, but currently more than 800 natural chemicals have been identified as having potential uses to improve human health. Therefore, our best strategy may be to preserve as much biodiversity as we can to improve our chances of finding the next critical drug.

Regulating Services

Natural ecosystems help to regulate environmental conditions. For example, humans currently add about 8 gigatons of carbon to the atmosphere annually (1 gigaton = 1 trillion kilograms), but only about 4 gigatons of carbon remain there. The rest is removed by natural ecosystems, such as tropical rainforests and oceans, which provide us with more time to address climate change than we would otherwise have (FIGURE 59.6). As we have already seen, ecosystems also are important in regulating nutrient and hydrologic cycles.

Support Systems

Natural ecosystems provide numerous support services that would be extremely costly for humans to generate. One example is pollination of food crops (FIGURE 59.7). The American Institute of Biological Sciences estimates that crop pollination in the United States by native species of bees and other insects, hummingbirds, and bats is worth roughly $3.1 billion in added food production. In addition to providing habitat for animals that pollinate crops, ecosystems provide natural pest control services because they provide habitat for predators that prey on agricultural pests. Although organic farmers, who rarely use synthetic pesticides, gain the most from these pest controls, conventional agriculture benefits as well.

Healthy ecosystems also filter harmful pathogens and chemicals from water, leaving humans with water that requires relatively little treatment prior to drinking. Without these water-filtering services, humans would have to build many new water treatment facilities that use expensive filtration technologies. New York City, for example, draws its water from naturally clean reservoirs in the Catskill Mountains. But residential development and tourism in the area has threatened to increase contamination of the reservoirs with

FIGURE 59.7 Support systems. Pollinators such as this honeybee play an essential role in ensuring the pollination of food crops such as cherries. *(Steffan and Alexandria Sailer/Ardea/Earth Scenes/Animals Animals)*

silt and chemicals. Building a filtration plant adequate to address these problems would cost $6 billion to $8 billion. For this reason, New York City and the U.S. Environmental Protection Agency have been working to protect sensitive regions of the Catskills.

Resilience

We have already seen that resilience ensures an ecosystem will continue to exist in its current state, which means it can continue to provide benefits to humans. Resilience depends greatly on species diversity. For example, several different species may perform similar functions in an ecosystem but differ in their susceptibility to disturbance. If a pollutant kills one plant species that contains nitrogen-fixing bacteria, but does not kill all plant species that contain nitrogen-fixing bacteria, the ecosystem can still continue to fix nitrogen (FIGURE 59.8).

Cultural Services

Ecosystems provide cultural or aesthetic benefits to many people. The awe-inspiring beauty of nature has instrumental value because it provides an aesthetic benefit for which people are willing to pay (FIGURE 59.9). Similarly, scientific funding agencies may award grants to scientists for research that explores biodiversity with no promise of any economic gain. Nevertheless, the research itself has instrumental value because the scientists and others benefit from these activities by gaining knowledge. While intellectual gain and aesthetic satisfaction may be difficult to quantify, they can be considered cultural services that have instrumental value.

FIGURE 59.8 Species diversity as a component of resilience. This prairie ecosystem contains a high diversity of grasses and wildflowers, including many species of nitrogen-fixing wildflowers. If one nitrogen-fixing species is eliminated, the lost function can be compensated for by another nitrogen-fixing species. *(Mike MacDonald/ChicagoNature.com)*

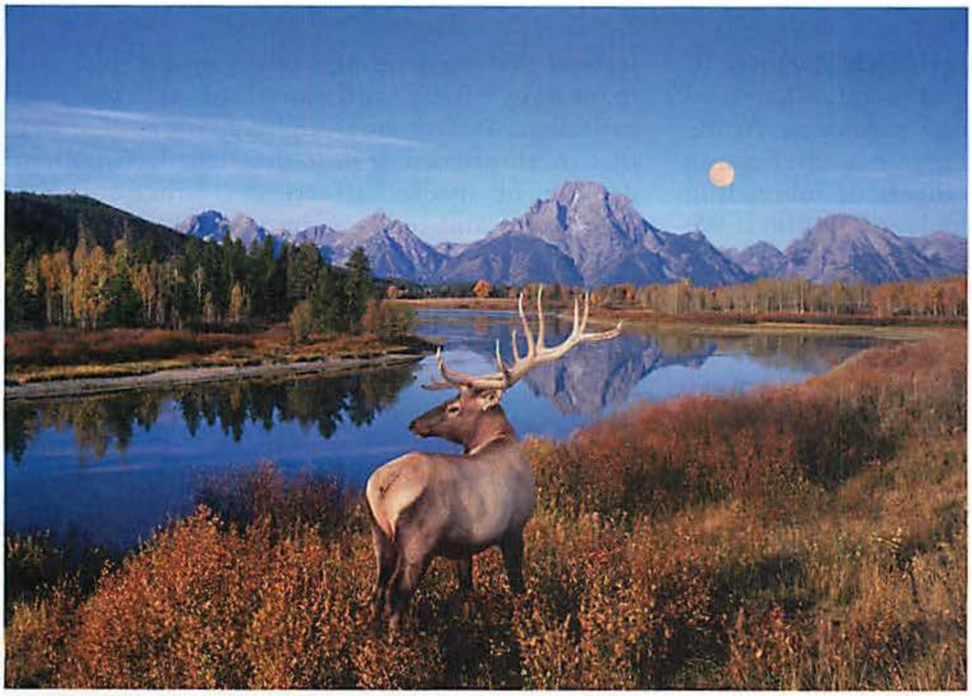

FIGURE 59.9 Cultural services. Many natural areas, such as this scene from the Grand Tetons National Park, provide aesthetic beauty valued by humans. *(Buddy Mays/Corbis)*

The Monetary Value of Ecosystem Services

Most economists believe that the instrumental values of an ecosystem can be assigned monetary values, and they are beginning to incorporate these values into their calculations of the economic costs and benefits of various human activities. However, assigning a dollar value is easier for some categories of ecosystem services than for others. In 1997, a team of scientists and economists attempted to estimate the total value of ecosystem services to the human economy. They considered replacement value—the cost to replace the services provided by natural ecosystems. They also looked at other factors, such as how property values were affected by location relative to these services—for example, oceanfront housing. Finally, they considered how much time or money people were willing to spend to use these services—for example, whether they were willing to pay a fee to visit a national park. Using this method, researchers estimated that ecosystem services were worth over $30 trillion per year, or more than the entire global economy at that time.

The Decline of Ecosystem Services

Because species help determine the services that ecosystems can provide, we would expect declines in species diversity to be associated with declines in ecosystem function. In the Millennium Ecosystem Assessment conducted in 2005, the most recent assessment conducted, scientists from around the world examined the current state of 24 ecosystem functions, including food production, pollination, water purification, and the cycling of nutrients such as nitrogen and phosphorus. Of these 24 different ecosystem functions, 15 were found to be declining or used at a rate that cannot be sustained. If we want to improve ecosystem functions, we need to improve the fate of the species and ecosystems that provide these services.

module

59

REVIEW

In this module, we have seen that declines in biodiversity are happening at a rate that may indicate the start of a sixth mass extinction. At the genetic level, a loss of diversity is a concern because it places species under the threat of inbreeding depression that can cause population declines. We have observed declines in the genetic diversity of both wild species and domesticated species such as crops and livestock. At the species level, we have learned that major groups of organisms, including mammals, fish, and amphibians, have all experienced extinctions and contain large groups that are threatened or near-threatened. This global decline in species affects the functioning of ecosystems and reduces the intrinsic and instrumental values that these ecosystems provide. In the next module, we will examine the many causes of these declines in biodiversity.

Module 59 AP® Review Questions

1. In a major extinction event, what is the minimum percentage of species that goes extinct?
   (a) 25 percent
   (b) 40 percent
   (c) 50 percent
   (d) 75 percent
   (e) 90 percent

2. What factor has played the largest role in decreased diversity of domesticated species?
   (a) A focus on increased yields
   (b) The use of genetic engineering
   (c) The adaptation to specific growing environments
   (d) The decreased number of pests
   (e) Increased seed storage efforts

3. Which group of organisms has had the greatest number of extinctions since 1500?
   (a) Birds
   (b) Amphibians
   (c) Mammals
   (d) Reptiles
   (e) Fish

4. The intrinsic value of an ecosystem
   (a) is the total monetary worth of its features.
   (b) is based on the goods the ecosystem produces.
   (c) considers the potential benefits that could be discovered in the ecosystem.
   (d) is the value it has independent of humans.
   (e) is the function of an ecosystem that humans cannot replicate.

5. Which is NOT a category of instrumental value?
   (a) Regulating services
   (b) Resilience
   (c) Provisions
   (d) Cultural services
   (e) Diversity

module 60

Causes of Declining Biodiversity

We have seen that declines in biodiversity are happening around the globe. In "Science Applied 2: How Should We Prioritize the Protection of Species Diversity?" on page 184, we discussed biodiversity hotspots, which are areas around the world rich in biodiversity. Many organisms in these biodiversity hotspots face threats of extinctions due to human activities. However, threats to biodiversity exist throughout the world. In this module, we build on the basics of population and community ecology from Chapter 5 to understand how a number of factors can all affect biodiversity.

Learning Objectives

After reading this module you should be able to

- discuss how habitat loss can lead to declines in species diversity.
- explain how the movement of exotic species affects biodiversity.
- describe how overharvesting causes declines in populations and species.
- understand how pollution reduces populations and biodiversity.
- identify how climate change affects species diversity.

Habitat loss is the major cause of declining species diversity

For most species, the greatest cause of decline and extinction is habitat loss. In modern times, the primary cause of habitat loss is human development that removes natural habitats and replaces them with homes, industries, agricultural fields, shopping malls, and roads. Many species can only thrive in a particular habitat within a narrow range of abiotic and biotic conditions. Species requiring such specialized habitats are particularly prone to population declines, especially when their favored habitat is limited, which restricts their distribution to a specific geographic area suitable only for a small population.

Altering distinctive characteristics of a habitat, such as removing trees or damming streams, has an effect on the organisms that live in that habitat. For example, for thousands of years the northern spotted owl (*Strix occidentalis caurina*) lived in old-growth forests—those dominated by trees that are hundreds of years old—in the northwestern United States and southwestern Canada (see Figure 29.1c on page 332). This habitat provided the ideal sites for nesting, roosting, and catching small mammals to eat. The removal of the old trees, for lumber and housing developments, has transformed much of the former old-growth forest into a different habitat (**FIGURE 60.1**). This habitat alteration reduces the number of northern spotted owls because they have fewer trees in which to nest and less forest in which to find food.

The map in **FIGURE 60.2** shows the changing face of forest habitats over the past few decades. As we saw in Chapter 6, much of the forest in the United States during the 1700s and 1800s was logged for lumber and cleared for agriculture. In recent decades, forested land has been increasing, although humans have often planted the new forests, which have a lower diversity of species than the original forests. At the same time, developing countries in South America, sub-Saharan Africa, and Southeast Asia are clearing their forests much as the United States and Europe did in years past. As a result, large declines in forest cover are occurring in developing countries that were once forested. It is currently unclear whether these countries will follow the pattern of Europe and North America and eventually allow their forested areas to increase.

Although deforestation receives a lot of attention, many other habitats are also being lost. According to the Millennium Ecosystem Assessment, approximately 70 percent of the woodland/shrubland ecosystem that borders the Mediterranean Sea has been lost. Similarly, across the globe we have lost nearly 50 percent of grassland habitats and 30 percent of desert habitats. Wetlands exhibit a mixed picture. Although the amount of wetland habitat is less than half of what

(a) (b)

FIGURE 60.1 Habitat loss. Habitat loss caused by humans is the largest threat to biodiversity. (a) Old-growth forests, such as this one in the Mount Rainier National Park in Washington State, serve as habitat for spotted owls. (b) After clear-cutting an old-growth forest for timber, such as this site in the Olympic National Forest in Washington State, the forest provides a very different habitat. It may take hundreds of years before the habitat again becomes suitable for the spotted owl. *(a: Stephen Matera/DanitaDelimont.com; b: Kent Foster/Science Source)*

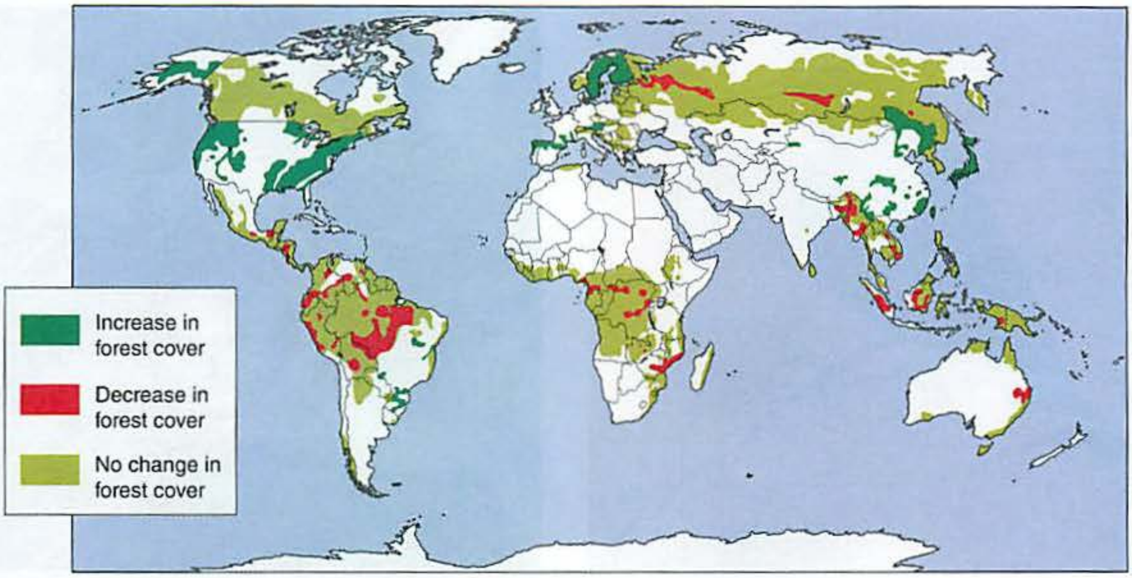

FIGURE 60.2 Changing forests. Some regions of the world experienced large declines in the amount of forested land from 1980 to 2000 while other regions have shown little change or have seen increases in forest cover. *(After Global Biodiversity Outlook 2, Convention on Biological Diversity, 2006)*

existed in the United States during the 1600s, from 1998 to 2004 the amount of freshwater wetland habitat actually increased. This overall growth occurred due to large increases in wetland habitat in the Great Lakes region. This growth offset a decline in coastal wetlands in the eastern United States and the Gulf of Mexico caused by growing human populations that built more roads, homes, and businesses.

In marine systems, there has been a sharp decline in the amount of living coral in the Caribbean Sea, as shown in **FIGURE 60.3**, from a high of 50 percent live coral in the 1970s to a mere 8 percent by 2012. Living coral provide habitat for thousands of other species, which makes them particularly vital to the persistence of marine habitats. The decline in coral is the result of human impacts including the warming of oceans (associated with global warming), increased pollution, and the removal of coral by collectors. This loss of coral habitat is occurring at a rapid rate throughout the world.

A species may decline in abundance or become extinct even without complete habitat destruction since a reduction in the size of critical habitat also can lead to extinctions through a variety of processes. As we saw in the case of the Florida panther, a smaller habitat supports a smaller population, reducing genetic diversity. Less habitat also reduces the variety of physical and climatic options available to individuals during periods of extreme conditions. The presence of cooler, high-altitude areas in a habitat, for example, allows animals a place to move during periods of hot weather. Also, loss of habitat can restrict the movement of migratory or highly mobile species. While many species can thrive in small habitats, other species, such as mountain lions, wolves, and tigers, require large tracts of relatively uninhabited, undisturbed land.

Smaller habitats can also cause increased interactions with other harmful species. For example, many songbirds in North America live in forests. When these birds make their nests near the edge of the forests—where the forest meets a field—they often have to contend with the brown-headed cowbird (*Molothrus ater*). The cowbird is a nest parasite—it does not build its own nest, but lays its eggs in the nests of several

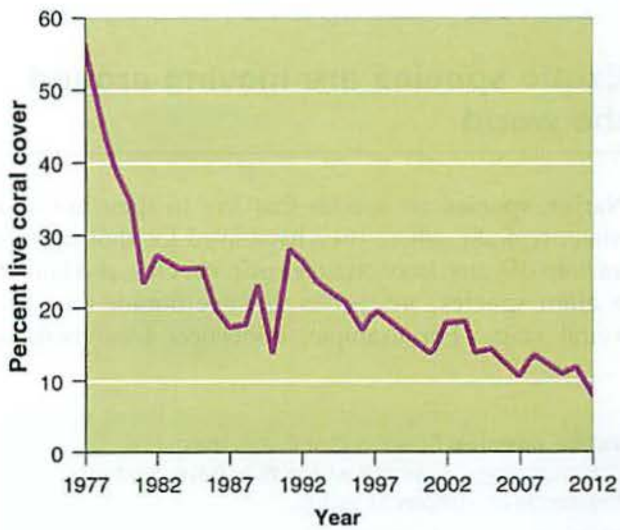

FIGURE 60.3 Changing coral reefs. The percentage of coral that remains alive in coral reefs has declined sharply in the Caribbean from 1977 to 2012. *(Tropical Americas Coral Reef Workshop, 2012)*

(a) (b)

FIGURE 60.4 Habitat fragmentation. (a) Increased fragmentation of forests has caused forest songbirds to come into increasing contact with the brown-headed cowbird. (b) The cowbird does not make its own nest. Instead, it lays its brown, spotted eggs in the nests of other species, such as this nest containing four blue eggs of the chipping sparrow (*Spizella passerina*).
(a: Jim Zipp/Ardea/Animals Animals; b: Paul J. Fusco/Science Source)

other species of birds (FIGURE 60.4). In this way the cowbird tricks forest birds into raising its offspring, which takes food away from the forest birds' own offspring. In some cases, the host bird will simply abandon the nest. As forests are broken up into smaller fragments, the proportion of forest near the edge increases and, therefore, the number of bird nests that are susceptible to brown-headed cowbirds increases. Over time, increased fragmentation has allowed brown-headed cowbirds to cause declines in many species of North American songbirds.

Exotic species are moving around the world

Native species are species that live in their historical range, typically where they have lived for thousands or millions of years. In contrast, **exotic species,** also known as **alien species,** are species that live outside their historical range. For example, honeybees (*Apis mellifera*) were introduced to North America in the 1600s to provide a source of honey for European colonists. Red foxes (*Vulpes vulpes*), now abundant in Australia, were introduced there in the 1800s for the purpose of fox hunts, which were popular in Europe at the time.

During the past several centuries, humans have frequently moved animals, plants, and pathogens around the world. Some species are also moved accidentally. For example, rats that have stowed away in shipping containers have ended up on distant oceanic islands. Because these islands never had rats or other ground predators, there had never been any natural selection against nesting on the ground, and numerous island bird species had evolved to nest on the ground. When the rats arrived, they found the eggs and hatchlings from ground nests an easy source of food, resulting in a high rate of extinction in ground-nesting birds in places such as Hawaii. Similar accidental movements have occurred for many pathogens, including exotic fungi that were introduced to North America nearly a century ago and have since killed nearly all American elm (*Ulmus americana*) and American chestnut (*Castanea dentata*) trees in eastern North America. Similarly, an exotic protist that causes avian malaria has driven many species of Hawaiian birds to extinction. Other movements of exotic species are intentional, such as exotic plants that are sold in greenhouses for houseplants and outdoor landscape plants, or exotic animals that are sold as pets or to game ranches that raise exotic species of large mammals for hunting.

Native species Species that live in their historical range, typically where they have lived for thousands or millions of years.

Exotic species A species living outside its historical range. *Also known as* **alien species.**

In most cases, exotic species fail to establish successful populations when they are introduced to a new region. For the small percentage of introductions that are successful, exotic species can live in their new surroundings and have no negative effect on the native species. In other cases, however, the exotic species rapidly increase in population size and cause harmful effects on native species. When exotic species spread rapidly across large areas, we call them **invasive species.** Rapid spread of invasive species is possible because invasive species, which have natural enemies in their native regions that act to control their population, often have no natural enemies in the regions where they are introduced. Two of the best-known examples of invasive exotic species in North America are the kudzu vine (*Pueraria lobata*) and the zebra mussel (*Dreissena polymorpha*).

The kudzu vine is native to Japan and southeast China but was introduced to the United States in 1876. Throughout the early 1900s, farmers in the southeastern states were encouraged to plant kudzu to help reduce erosion in their fields. By the 1950s, it became apparent that the southeastern climate was ideal for kudzu, with growth rates of the vine approaching 0.3 m (1 foot) *per day*. Because herbivores in the region do not eat kudzu, the species has no enemies and can spread rapidly. The vine grows up over most wildflowers and trees and shades them from the sunlight, causing the plants to die. Indeed, the vine grows over just about anything that does not move (**FIGURE 60.5**). Kudzu currently covers approximately 2.5 million hectares (7 million acres) in the United States.

FIGURE 60.5 The spread of the exotic kudzu vine. The fast-growing kudzu vine is native to Asia but was introduced to the United States to control erosion. It has since spread rapidly, growing over the top of nearly anything that does not move. *(Melissa Farlow/National Geographic Creative/Getty Images)*

The zebra mussel is native to the Black Sea and the Caspian Sea in eastern Europe and western Asia. Over the years, large cargo ships that traveled in these seas unloaded their cargo in the ports of the Black Sea and Caspian Sea and then pumped seawater into the holding tanks to ensure that the ship sat low enough in the water to remain stable. This water that is pumped into the ship is called ballast water. When the ships arrived in the St. Lawrence River and the Great Lakes, they loaded on new cargo and no longer needed the weight of the ballast water, which they pumped out of the ship into local waters. One consequence of transporting ballast water from Asia to North America is that many aquatic species from Asia, including zebra mussels, have been introduced into the aquatic ecosystems of North America. Because the St. Lawrence River and the Great Lakes provided an ideal ecosystem for the zebra mussel, and because a single zebra mussel can produce up to 30,000 eggs, the mussel spread rapidly through the Great Lakes ecosystem. On the positive side, because the mussels feed by filtering the water, they remove large amounts of algae and some contaminants, which, to some degree, counteracts the cultural eutrophication that has occurred in the Great Lakes ecosystem. On the negative side, the zebra mussels physically crowd out many native mussel species and the zebra mussels can consume so much algae that they negatively affect native species that also need to consume the algae. Moreover, the invasive mussels can achieve such high densities that they can clog intake pipes and impede the flow of water on which industries and communities rely.

A new threat to the Great Lakes is the silver carp (*Hypophthalmichthys molitrix*), a fish that is native to Asia but has been transported around the world in an effort to consume excess algae that accumulates in aquaculture operations and the holding ponds of sewage treatment plants. After being brought to the United States, some of the fish escaped and rapidly spread through many of the major river systems, including the Mississippi River. Over the years, the carp population has expanded northward, and by 2010 it approached a canal where the Mississippi River connects to Lake Michigan. Although researchers detected the DNA of the carp in water samples from the Great Lakes from 2009 to 2011, substantial netting efforts in the spring of 2013 failed to find any of the fish in the lakes. There are two major concerns about this invading fish. First, scientists worry that it will outcompete native species of fish that also consume algae. Second, the silver carp has an unusual behavior; it jumps out of

Invasive species A species that spreads rapidly across large areas.

FIGURE 60.6 Silver carp invading the Mississippi River. The silver carp has been introduced into the Mississippi River from Asia and is quickly heading toward an invasion of the Great Lakes. *(Chris Olds/U.S. Fish & Wildlife Service)*

the water when startled by passing boats (FIGURE 60.6). Given that the carp can grow to 18 kg (40 pounds) and jump up to 3 m (10 feet) into the air, this poses a major safety issue to boaters.

Around the world, invasive exotic species pose a serious threat to biodiversity by acting as predators, pathogens, or superior competitors to native species. Some of the most complete data exist in Europe. As FIGURE 60.7 shows, during the past 100 years, Europe has experienced a steady increase of nearly 2,000 exotic species in terrestrial ecosystems. Additional species have been introduced into freshwater and marine ecosystems. A number of efforts are currently being used to reduce the introduction of invasive exotic species, including the inspection of goods coming into a country and the prohibition of wooden packing crates made of untreated wood that could contain insect pests.

Overharvesting causes declines in populations and species

Hunting, fishing, and other forms of harvesting are the most direct human influences on wild populations of plants and animals. Most species can be harvested to some degree, but a species is overharvested when individuals are removed at a rate faster than the population can replace them. In the extreme, overharvesting of a species can cause extinction. In the seventeenth century, for example, ships sailing from Europe stopped for food and water at Mauritius, an uninhabited island in the Indian Ocean. On Mauritius, the sailors would hunt the dodo (*Raphus cucullatus*), a large flightless bird that had no innate fear of humans because it had never seen humans during

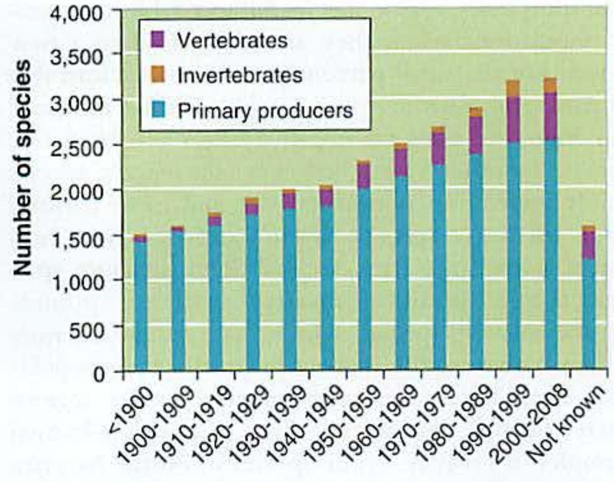

FIGURE 60.7 Exotic species. Over the decades, there has been a steady increase in the number of exotic species in Europe. This example shows the number of exotic species recorded in terrestrial ecosystems. *(Data from European Environment Agency,* EU 2010 Biodiversity Baseline, *2010)*

its evolutionary history (FIGURE 60.8). The dodo, unable to protect itself from human hunters and the rats (introduced by humans) that consumed dodo eggs and hatchlings, became extinct in just 80 years. This

FIGURE 60.8 Overharvesting. The dodo was a large flightless bird that served as an easy source of meat for sailors and settlers on the island of Mauritius. Because it evolved on an island with no large predators or humans, the dodo had no instinct to fear humans. *(Stock Montage/Getty Images)*

same scenario appears to have taken place with many other large animal species as well. These animals include the giant ground sloths, mammoths, American camels of North and South America, and the 3.7 m (12 feet) tall moa birds of New Zealand. Each species became extinct soon after humans arrived, suggesting that the animals' demise may have been due to overharvesting.

Overharvesting has also occurred in the more recent past. In the 1800s and early 1900s, for example, market hunters slaughtered wild animals to sell their parts on such a scale that many species, including the American bison, declined dramatically. Bison were once abundant on the western plains, with estimates ranging from 60 to 75 million individuals. By the late 1800s fewer than 1,000 were left. This means that 99.999 percent of all bison were killed. Following enactment of legal protections, the bison population today has increased to more than 500,000, including both wild bison and bison raised commercially for meat.

Not all species harvested by market hunters fared as well as the American bison. The passenger pigeon was once one of the most abundant species of birds in North America. Population estimates range from 3 to 5 billion birds in the nineteenth century. In fact, during annual migrations, people observed continuous flocks of pigeons flying overhead for 3 days straight in densities that blocked out most of the sun. Breeding flocks could cover 40,000 ha (100,000 acres) with 100 nests built into each tree. With such high densities, market hunters could shoot or net the birds in very large numbers and fill train cars with harvested pigeons to be sold in eastern cities. This overharvesting, combined with the effects of forest clearing for agriculture, caused the passenger pigeon to decline quickly. The last passenger pigeon died in 1914 at the Cincinnati Zoo.

During the past century, regulations have been passed to prevent the overharvesting of plants and animals. In the United States, for example, state and federal regulations restrict hunting and fishing of game animals to particular times of the year and limit the number of animals that can be harvested. Similar agreements have been reached among countries through international treaties. In general, these regulations have proven very successful in preventing species declines caused by overharvesting. In some regions of the world, however, harvest regulations are not enforced and illegal poaching, especially of large, rare animals that include tigers, rhinoceroses, and apes, continues to threaten species with extinction. Harvesting of rare plants, birds, and coral reef dwellers for private collections has also jeopardized these species.

Plant and Animal Trade

For some species, the legal and illegal trade in plants and animals represents a serious threat to their ability to persist in nature. One of the earliest laws in the United States to control the trade of wildlife was the **Lacey Act.** First passed in 1900, the act originally prohibited the transport of illegally harvested game animals, primarily birds and mammals, across state lines. Over the years, a number of amendments have been added so that the Lacey Act today forbids the interstate shipping of all illegally harvested plants and animals.

At the international level, the United Nations **Convention on International Trade in Endangered Species of Wild Fauna and Flora,** also known as **CITES,** was developed in 1973 to control the international trade of threatened plants and animals. Today, CITES is an international agreement among 175 countries throughout the world. The IUCN maintains a list of threatened species known as the **Red List.** Each member country assigns a specific agency to monitor and regulate the import and export of animals on the list. For example, in the United States, the U.S. Fish and Wildlife Service conducts this oversight.

Despite such international agreements, much illegal plant and animal trade still occurs throughout the world. In 2008, a report by the Congressional Research Service estimated that illegal trade in wildlife was worth \$5 billion to \$20 billion annually. In some cases, animals are sold for fur or for body parts that are thought to have medicinal value. In other cases, rare animals are in demand as pets. For example, in 2001 a population of the Philippine forest turtle (*Siebenrockiella leytensis*), once thought to be extinct, was discovered on a single island in the Philippines (FIGURE 60.9). This animal, one of the most endangered species in the world, cannot be traded legally, but demand for it as a pet has caused it to be sold illegally and the last remaining population has declined sharply in only a few years. A single turtle sells for \$50 to \$75 in the Philippines and up to \$2,500 in the United States and Europe. Similar cases of illegal trade occur in rare species of trees for lumber such as big-leaf mahogany (*Swietenia macrophylla*), rare species of plants for medicine such as goldenseal (*Hydrastis canadensis*), and many rare species of orchids for their beautiful flowers.

Lacey Act A U.S. act that prohibits interstate shipping of all illegally harvested plants and animals.

Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) A 1973 treaty formed to control the international trade of threatened plants and animals.

Red List A list of worldwide threatened species.

FIGURE 60.9 Species declines due to the pet trade. The only remaining population of this turtle lives on a single island in the Philippines. Although protected by law, illegal trade has caused a rapid decline of this species in the wild. *(NHPA/Photoshot)*

Sometimes even when trade in a particular species is legal, it can pose a potential long-term threat to species persistence. In the southwestern United States, for example, there is a growing movement to reduce water use by replacing grass lawns with desert landscapes. One of the unintended consequences is the increased demand for cacti and other desert plants that are collected from the wild. Sales are currently estimated to be $1 million annually. Given the slow growth of desert plants, this increased demand is causing heightened concern for these plant populations in the wild.

Pollution can have harmful effects on species

In Chapters 14 and 15, we saw how water and air pollution harm ecosystems. Threats to biodiversity come from toxic contaminants such as pesticides, heavy metals, acids, and oil spills. Other contaminants, such as endocrine disrupters, can have nonlethal effects that prevent or inhibit reproduction. Pollution sources that cause declines in biodiversity also include the release of nutrients that cause algal blooms and dead zones as well as thermal pollution that can make water bodies too warm for species to survive.

In 2010, for example, an oil platform in the Gulf of Mexico owned by BP and named the *Deepwater Horizon* exploded, causing a massive release of oil that lasted for several months. As we discussed in Chapter 14, the release of oil caused a tremendous amount of death across a wide range of animal species including sea turtles, pelicans, fish, and shellfish. In response to the massive oil spill, BP released hundreds of thousands of liters of oil dispersant, a chemical designed to break up large areas of oil into tiny droplets that can be consumed by specialized species of bacteria. However, the dispersant is also toxic to many species of animals. The total impact of the spilled oil and applied dispersants on the wildlife of the Gulf of Mexico may not be known for many years.

Climate change has the potential to affect species diversity

We have mentioned climate change in previous chapters and will discuss it in detail in Chapter 19. As a threat to biodiversity, the primary concern about climate change is its effect on patterns of temperature and precipitation in different regions of the world. In some regions, a species may be able to respond to warming temperatures and changes in precipitation by migrating to a place where the climate is well suited to the species niche. In other cases, this is not possible. For example, in southwestern Australia, a small woodland/shrubland peninsula exists on the edge of the continent with a much larger area of subtropical desert farther inland (see Figure 12.3 on page 123). Scientists expect conditions on the peninsula to become drier during the next 70 years. If this occurs, many species of plants in this small ecosystem will not have a nearby hospitable environment to which they can migrate, since the surrounding desert ecosystem is already too dry for them. An examination of 100 species of plants in the area (all from the genus *Banksia*) has led scientists to project that 66 percent of the species will decline in abundance and up to 25 percent will become extinct. As we will see in Chapter 19, many species in the world are expected to be affected by climate change.

module

60

REVIEW

In this module, we learned that the biodiversity of our planet is declining for a number of reasons. The primary causes of this decline are the loss of habitats and the fragmentation of habitats that species need to survive and reproduce. Exotic species are being moved around the world with the increased global movement of people and materials. Many populations of these exotic species remain small and cause no discernible harm, but some become invasive species that spread quickly and have harmful effects on native species. Overharvesting species can cause larger declines in population sizes and, in some cases, extinction. Current regulations within and among countries are designed to limit harvesting to sustainable levels, although these regulations are not always successfully enforced. Toxic compounds including pesticides, heavy metals, and spilled oil can also be detrimental to species either by direct lethal effects or by altering communities and ecosystems. Finally, climate change has the potential to alter populations and the long-term persistence of species, but more time is needed to determine if these predictions will come true. In the next module, we will examine past and current efforts to conserve biodiversity.

Module 60 AP® Review Questions

1. The most significant cause of species decline and extinction throughout the world is
   (a) habitat loss.
   (b) overharvesting.
   (c) pollution.
   (d) climate change.
   (e) invasive species.

2. Invasive species are
   (a) usually not a threat to biodiversity.
   (b) rare in island habitats.
   (c) successful due to a lack of natural enemies.
   (d) mostly specialist species.
   (e) often unable to compete effectively in the new environment.

3. Passenger pigeons were driven extinct primarily by
   (a) habitat loss.
   (b) overharvesting.
   (c) pollution.
   (d) climate change.
   (e) invasive species.

4. The Lacey Act
   (a) provides protected habitats for a number of threatened species.
   (b) forbids the interstate shipping of illegally harvested plants and animals.
   (c) provides harvesting quotas and prevents overharvesting.
   (d) prevents the spread of invasive species to the United States.
   (e) gives penalties for polluting ecosystems, especially water.

5. The primary impact of climate change on species diversity is expected to be
   (a) an increased number of extreme weather events.
   (b) an increased variability in weather.
   (c) decreased precipitation worldwide.
   (d) changes in available habitat because of changing temperatures.
   (e) the increased ability of species to disperse.

module

61

The Conservation of Biodiversity

It is important that we consider how to protect and increase biodiversity because of the large number of factors that can reduce biodiversity. There are two general approaches to conserving biodiversity: the single-species approach and the ecosystem approach. In this module, we explore each of these approaches.

Learning Objectives

After reading this module you should be able to

- identify legislation that focuses on protecting single species.
- discuss conservation efforts that focus on protecting entire ecosystems.

Conservation legislation often focuses on single species

The single-species approach to conserving biodiversity focuses our efforts on one species at a time. When a species declines significantly, the natural response is to encourage a population rebound by improving the conditions in which that species exists. This might be accomplished by providing additional habitat, reducing the harvest, or reducing the presence of a contaminant that is impairing survival or reproduction. When the population of a species has declined to extremely low numbers, sometimes the remaining few individuals will be captured and brought into captivity. Captive animals are bred with the intention of returning the species to the wild. A well-known example of captive breeding occurred with the California condor. As we discussed in Chapter 6, the condor had declined to a mere 22 birds in 1987. Thanks to captive breeding and several improvements in the condor's habitat, the population in 2013 was more than 400 birds. Programs such as these are a major function of zoos and aquariums around the world.

Marine Mammal Protection Act A 1972 U.S. act to protect declining populations of marine mammals.

The Marine Mammal Protection Act

In the United States, the single-species approach to conservation formed the foundation of the *Marine Mammal Protection Act* and the *Endangered Species Act*. The **Marine Mammal Protection Act** prohibits the killing of all marine mammals in the United States and prohibits the import or export of any marine mammal body parts. Only the U.S. Fish and Wildlife Service and the National Marine Fisheries Service are allowed to approve any exceptions to the act. The act was passed in 1972 in response to declining populations of many marine mammals, including polar bears, sea otters, manatees (*Trichechus manatus*), and California sea lions (*Zalophus californianus*) (FIGURE 61.1).

(a)

(b)

FIGURE 61.1 Protected marine mammals. The Marine Mammal Protection Act protects marine mammals in the United States from being killed. (a) Sea otter, (b) California sea lion. *(a: Hal Beral/V&W/The Image Works; b: Craig K. Lorenz/Science Source)*

The Endangered Species Act

In Chapter 10, we noted that the Endangered Species Act is a 1973 law designed to protect species from extinction. This act authorizes the U.S. Fish and Wildlife Service to determine which species can be listed as threatened species or *endangered species* and prohibits the harming of such species, including prohibitions on the trade of listed species, their fur, or their body parts. You might recall that earlier in this chapter we discussed the international definitions of threatened and near-threatened as used by the IUCN (see page 636): Threatened species have a high risk of extinction in the future and near-threatened species are very likely to become threatened in the future. In the United States, an **endangered species** is defined as a species that is in danger of extinction within the foreseeable future throughout all or a significant portion of its range whereas a **threatened species** is defined as any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range. As you can see, the U.S. definition of endangered is similar to the international definition for threatened and the U.S. definition of threatened is similar to the international definition of near-threatened.

The Endangered Species Act was first passed in 1973 and has been amended several times since then. From an international perspective, the act also implements the international CITES agreement that we discussed in the previous module. To assist in the conservation of threatened and endangered species, the act authorizes the government to purchase habitat that is critical to the conservation of these species and to develop recovery plans to increase the population of threatened and endangered species. This is often one of the most important steps in allowing endangered species to persist.

In 2013, the species that have been listed as threatened or endangered in the United States include 227 invertebrate animals, 394 vertebrate animals, and 815 plants. An additional 245 species are currently being considered for listing, a process that can take several years. Once listed, however, many threatened and endangered species have experienced stable or increasing populations. Indeed, some species have experienced sufficient increases in numbers to be removed from the endangered species list; these include the bald eagle (FIGURE 61.2), peregrine falcon, American alligator, and the eastern Pacific population of the gray whale (*Eschrichtius robustus*). Other species are currently increasing in number and may be taken off the list in the future. The gray wolf, for example, was reintroduced into Yellowstone National Park to help improve the species' abundance in the United States and it is now no longer endangered.

The Endangered Species Act has sparked a great deal of controversy in recent years because it permits restriction of certain human activities in areas where listed species live, including how landowners use their land. For example, some construction projects have been prevented or altered to accommodate threatened or endangered species. Organizations whose activities are restricted by the Endangered Species Act often try to pit the protection of listed species against the jobs of people in the region. In the

Endangered species A species that is in danger of extinction within the foreseeable future throughout all or a significant portion of its range.

Threatened species According to U.S. legislation, any species that is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.

FIGURE 61.2 Bringing back endangered species. Habitat protection and reduced contaminants in the environment have allowed bald eagle populations to increase to the point where they could be taken off the Endangered Species List. *(Ron Niebrugge/Aurora Photos)*

1990s, for example, logging companies wanted to continue logging the old-growth forest of the Pacific Northwest. As we discussed earlier in this chapter, these forests are home to the threatened northern spotted owl and many other species that depend on old-growth forest. Automation had caused a large decline in the number of logging jobs over the preceding several decades, and many loggers perceived the Endangered Species Act as a further threat to their livelihood. They denounced the act because they said it placed more value on the spotted owl than it did on the humans who depended on logging. In the end, a compromise allowed continued logging on some of the old-growth forest while the rest became protected habitat.

During the past decade, several politicians have attempted to weaken the Endangered Species Act. However, strong support from the public and scientists has allowed it to retain much of its original power to protect threatened and endangered species. The biggest current challenge is a lack of sufficient funds and personnel required to implement the law.

The Convention on Biological Diversity

Protection of biodiversity is an international concern. In 1992, world nations came together and created the **Convention on Biological Diversity,** which is an international treaty to help protect biodiversity. The treaty had three objectives: conserve biodiversity, sustainably use biodiversity, and equitably share the benefits that emerge from the commercial use of genetic resources such as pharmaceutical drugs.

Convention on Biological Diversity An international treaty to help protect biodiversity.

In 2002, the convention developed a strategic plan to achieve a substantial reduction in the worldwide rate of biodiversity loss by 2010. The nations that signed this agreement recognized both the instrumental and intrinsic values of biodiversity. In 2010, the convention evaluated the current trends in biodiversity around the world and concluded that the goal had not been met. They identified the following trends from 2002 to 2010:

- On average, species at risk of extinction have moved closer to extinction.
- One-quarter of all plant species are still threatened with extinction.
- Natural habitats are becoming smaller and more fragmented.
- The genetic diversity of crops and livestock is still declining.
- There is a widespread loss of ecosystem function.
- The causes of biodiversity loss have either stayed the same or increased in intensity.
- The ecological footprint of humans has increased.

Collectively, the message emerging from the convention is not very positive. From the perspectives of genetic diversity, species diversity, and ecosystem services, all of the trends during the 8-year period continue to move in the wrong direction.

Some conservation efforts focus on protecting entire ecosystems

Awareness of a potential sixth mass extinction in which humans have played a major role has brought a growing interest in the ecosystem approach to conserving biodiversity. This approach recognizes the benefit of preserving particular regions of the world, such as biodiversity hotspots. Protecting entire ecosystems has been one of the major motivating factors in setting aside national parks and marine reserves. In some cases, these areas were originally protected for their aesthetic beauty, but today they are also valued for their communities of organisms. The amount of protected land has increased dramatically throughout the world since 1960. As an example of this increase, FIGURE 61.3 shows changes in the amount of protected land worldwide since 1900.

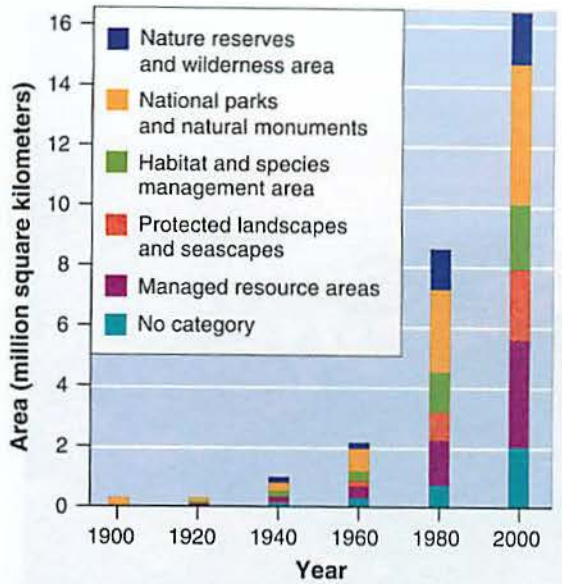

FIGURE 61.3 Changes in protected land. Since the 1960s, there has been a large increase in the amount of land that is under various types of protection throughout the world. *(Data from* Global Biodiversity Outlook 2, *Convention on Biological Diversity, 2006)*

When protecting ecosystems to conserve biodiversity, a number of factors must be taken into consideration including the size and shape of the protected area. We must also consider the amount of connectedness to other protected areas and how best to incorporate conservation while recognizing the need for sustainable habitat use for human needs.

The Size, Shape, and Connectedness of Protected Areas

A number of questions arise when we consider protecting areas of land or water. For example, how large should the designated area be? Should we protect a single large area or several smaller areas? Does it matter whether protected areas are isolated or if they are near other protected areas? To help us answer these questions, we can return to our discussion of the theory of island biogeography from Chapter 6.

As you may recall, the theory of island biogeography looks at how the size of islands and the distance between islands and the mainland affect the number of species that are present on different islands. Larger islands generally contain more species because they support larger populations of each species, which makes them less susceptible to extinction. Larger islands also contain more species because they typically contain more habitats and, therefore, provide a wider range of niches for different species to occupy. The distance between an island and the mainland, or between one island and another, is another crucial factor, since more species are capable of dispersing to close islands than to islands farther away.

Although the theory of island biogeography was originally applied to oceanic islands, it has since been applied to islands of protected areas in the midst of less hospitable environments. For example, we can think of all the state and national parks, natural areas, and wilderness areas as islands surrounded by environments subject to high levels of human activity, including agricultural fields, logged forests, housing developments, and cities (**FIGURE 61.4**). These areas provide habitats for species and places to stop and rest for migrating species. Applying the theory of island biogeography from this perspective gives us some idea of the best ways to design and manage protected areas. For example, when protected areas are far apart, it is less likely that species can travel among them. This means that when a species has been lost from one ecosystem, it will be harder for individuals of that species from other ecosystems to recolonize it. So when we create smaller areas, they should be close enough for species to move among them easily.

Decisions regarding the design of protected areas can also be informed by the concept of metapopulations. As we learned in Chapter 6, a metapopulation is a collection of smaller populations connected by occasional dispersal of individuals along habitat corridors. Each population fluctuates somewhat independently of the other populations and a population that declines or goes extinct, due to a disease for example, can be rescued by dispersers from a neighboring population. So if we set aside multiple protected areas, and recognize the need for connecting habitat corridors, a species is more likely to be protected from extinction by a decimating event such as a disease or natural disaster that could eliminate all individuals in a single protected area.

The concepts of island biogeography and metapopulations raise an interesting dilemma for conservation efforts. If we have limited resources to protect the biodiversity of a region, should we protect a single large area or several small areas? A single large area would support larger populations, but a species is more likely to survive a disease or natural disaster if it occupies several different areas. The debate over the best approach is known as SLOSS, which is an acronym for "single large or several small." While both approaches have their merits, in reality, human development and other factors often mean that only one of the two strategies is available. For example, due to human development of a region, there may simply not be a single large area available to protect, so the only available strategy is to protect several small areas. A final consideration regarding the size and shape of protected areas is the amount of *edge habitat* that an area contains.

FIGURE 61.4 Habitat islands provide habitat. Central Park is an extreme example of an island of hospitable habitat surrounded by an urban environment that is not hospitable to most species. *(Michael S. Yamashita/National Geographic Stock)*

Edge habitat occurs where two different communities come together, typically forming an abrupt transition, such as where a grassy field meets a forest. While some species will live in either field or forest, others, like the brown-headed cowbird, specialize in living at the forest edge. So another challenge of protecting many small areas is the comparatively larger amount of edge habitat. When we protect several small forests, for example, the proliferation of species such as the cowbird in this larger amount of edge habitat can have a detrimental effect on songbirds that typically live farther inside a forest.

Biosphere Reserves

In Chapter 10 we saw that managing national parks and other protected areas so they serve multiple users can be a challenge. While we want to make places of great natural beauty available to everyone, when large numbers of people use an area for recreation, at least some degradation is very likely. To address this problem, the United Nations Educational, Scientific and Cultural Organization (UNESCO) developed the innovative concept of *biosphere reserves*. **Biosphere reserves** are protected areas consisting of zones that vary in the amount of permissible human impact. These reserves protect biodiversity without excluding all human activity. FIGURE 61.5 shows the different zones in a hypothetical biosphere reserve. The central core is an area that receives minimal human impact and is therefore the best location for preserving biodiversity. A buffer zone encircles the core area. Here, modest amounts of human activity are permitted, including tourism, environmental education, and scientific research facilities. Farther out is a transition area containing sustainable logging, sustainable agriculture, and residences for the local human population.

Designing reserves with these three zones represents an ideal scenario. In reality, biosphere reserves can take many forms depending on their location, though all attempt to maintain low-impact core areas. As of 2013 there are 610 biosphere reserves worldwide—47 in the United States—with a total of 117 nations participating.

Edge habitat Habitat that occurs where two different communities come together, typically forming an abrupt transition, such as where a grassy field meets a forest.

Biosphere reserve Protected area consisting of zones that vary in the amount of permissible human impact.

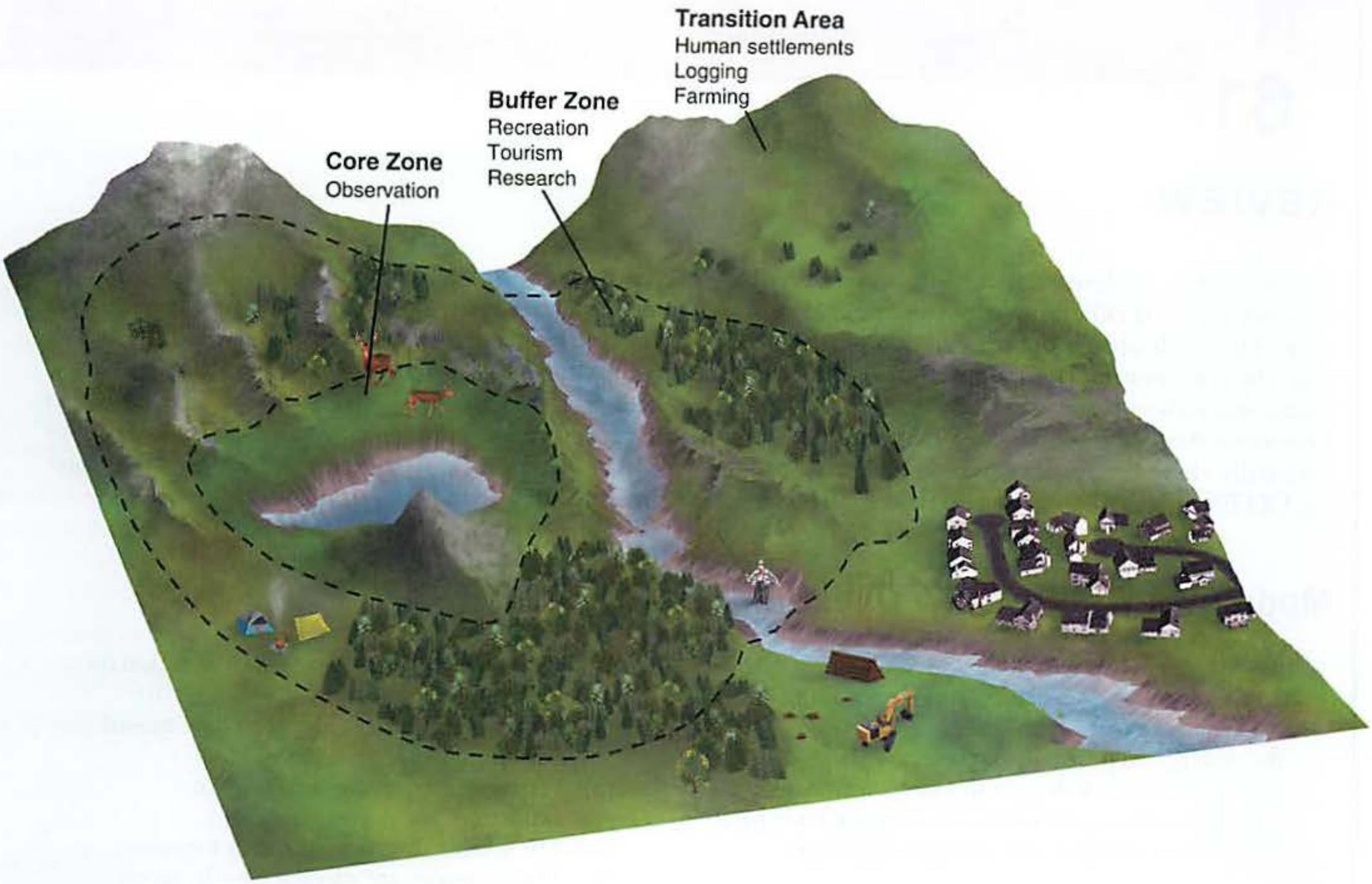

FIGURE 61.5 Biosphere reserve design. Biosphere reserves ideally consist of core areas that have minimal human impact and outer zones that have increasing levels of human impacts.

One well-known biosphere reserve is Big Bend National Park in Texas. The park itself serves as the core area and receives relatively little human impact, although hikers are permitted to walk through the beautiful desert landscapes and tree-covered mountain peaks. The park contains several dozen threatened and endangered plant and animal species. It also contains more than 1,000 species of plants and 400 species of birds, many of which pass through the Big Bend region during their annual spring and fall migrations. Outside the boundaries of the park is a region of increased human impact including tourist facilities, human settlements, and agriculture (**FIGURE 61.6**).

FIGURE 61.6 Biosphere reserve. Big Bend National Park, located in southwest Texas, serves as a low-impact core area of the Big Bend biosphere reserve. *(Tom Till/Alamy)*

module

61

REVIEW

In this module, we learned that efforts to conserve biodiversity focus on either single species or entire ecosystems. The single-species approach is often the approach taken by conservation legislation. In the United States, single-species legislation includes the Marine Mammal Protection Act and the Endangered Species Act. Internationally, there are treaties that protect species, including CITES and the Convention on Biological Diversity.

A number of conservation efforts have focused on protecting entire ecosystems by considering the concepts of island biogeography and metapopulations. To reach a compromise between complete protection, on the one hand, and human use of habitats, on the other, scientists have developed the concept of biosphere reserves in which core areas receive greater protection while outer areas are allowed to have sustainable impacts.

Module 61 AP® Review Questions

1. The Marine Mammal Protection Act
   (a) allows states to make exceptions regarding the killing of marine mammals.
   (b) was passed primarily to protect whales.
   (c) prohibits the killing of all marine mammals.
   (d) allows the import of marine mammal body parts.
   (e) protects sharks as well as marine mammals.

2. Which is NOT true of the Endangered Species Act?
   (a) It is an example of the single-species approach to conservation.
   (b) It prohibits the hunting or harvesting of some listed species.
   (c) It includes the development of recovery plans for listed species.
   (d) It uses a different definition for threatened than the IUCN.
   (e) It has resulted in the delisting of several species after successful population growth.

3. Problems with protecting many small habitats include
   I. increased proportions of edge habitats.
   II. increased dispersal between populations.
   III. the need for corridors between some protected species.

   (a) I only
   (b) I and III only
   (c) II only
   (d) II and III only
   (e) III only

4. Which is a trend identified by the Convention on Biological Diversity between 2002 and 2010?
   (a) Over half of threatened species have moved away from extinction.
   (b) Very few plant species are at risk of extinction.
   (c) The genetic diversity of crops is increasing.
   (d) Marine species are affected most by recent biodiversity losses.
   (e) The human ecological footprint has increased.

5. According to the theory of island biogeography
   (a) when conservation areas are close to each other, more species will persist.
   (b) species on islands far from the mainland are at the least risk of extinction.
   (c) multiple small conservation areas will protect species better than one large area of the same size.
   (d) conservation areas should be connected with corridors to increase migration.
   (e) edge habitat is important to protect for increased diversity.

Swapping Debt for Nature

Preserving biodiversity is expensive. A case in point is the money required to set aside terrestrial or aquatic areas for protection. As an example, if the land is privately owned, it must be purchased. Indirect costs can also be high. Not using the land, water, or other natural resources—such as wood materials, metals, and fossil fuels—results in lost income. Finally, the costs of maintaining the protected area can be prohibitive, ranging from monitoring the biodiversity to hiring guards to prevent illegal activities such as poaching. Given the fact that preserving biodiversity is expensive, how can the developing nations of the world, which contain so much biodiversity but have such little wealth, afford it?

In 1984, Thomas Lovejoy from the World Wildlife Fund came up with an idea that would help protect large areas of land but at the same time improve the economic conditions of developing countries. Lovejoy observed that developing nations possessed much biodiversity but were often deep in debt to wealthier, developed countries. Developing countries borrowed large amounts for the purpose of improving economic conditions and political stability. While the developing countries were slowly repaying their loans with interest, some had fallen so far behind on these payments that it seemed unlikely the loans would ever be repaid in full. These debtor countries had little money left over for investment in an improved environment after they had paid their loans to developed countries. Lovejoy considered the possibility that the wealthy countries might be willing to let debtor nations swap their debt in exchange for investing in the conservation of the biodiversity of the debtor nations.

The "debt-for-nature" swap has been used several times in Central and South America. In these swaps, the United States government and prominent environmental organizations provide cash to pay down a portion of a country's debt to the United States. The debt is then transferred to environmental organizations within that country with the debtor government making payments to the environmental organizations rather than to the United States. This does not mean that the country is out of debt, just that it now sends its loan payments to the environmental organizations for the purpose of protecting the country's biodiversity. In short, the indebted country switches from sending its money out of the country to investing in its own environmental conservation.

One of the largest debt-for-nature swaps recently happened in the Central American country of Guatemala. The United States government paired with two conservation organizations to provide $17 million to Guatemala. Over a period of 15 years, this amount, with interest, would have grown to more than $24 million, or about 20 percent of Guatemala's debt to the United States. In exchange, Guatemala agreed to pay $24 million over 15 years to improve conservation efforts in four areas of the country, including the purchase of land, the prevention of illegal logging, and future grants to conservation organizations helping to document and preserve the local biodiversity. The four areas include two ecosystems—mangrove forests and tropical forests. Each forms a core area within a biosphere reserve that contains a large number of rare and endangered species including the jaguar (*Panthera onca*). More than twice the size of Yellowstone National Park in the United States, this reserve offers important protection to biodiversity while also preserving historic Mayan temples that are part of Guatemala's cultural heritage and allowing sustainable use of some of the forest by local people.

Since the program began in 1998, the United States has used the debt-for-nature swap to protect tropical forests in 15 countries from Central America to the Philippines. To take part in the swap program, the countries are required to have a democratically elected government, a plan for improving their economies, and an agreement to cooperate with the United States on issues related to combating drug trafficking and terrorism. The results of these agreements have been encouraging. In Belize, for example, a debt-for-nature swap allowed 9,300 ha (23,000 acres) to be protected and an

Swapping debt for nature in Guatemala. The Maya Biosphere Reserve is one of four areas of Guatemala that will be better protected under an agreement between the governments of the United States and Guatemala as well as several conservation organizations. *(Rob Crandall/The Image Works)* additional 109,000 ha (270,000 acres) to be managed for conservation. In Peru, a $10.6 million debt-for-nature swap led to the protection of more than 11 million ha (27 million acres) of tropical forest. Although these arrangements are only currently being applied to tropical forests, there is no inherent reason that this unique, modern-day conservation strategy would not also work in many other developing countries around the world.

Critical Thinking Questions

1. In debt-for-nature swaps, why might the United States require that developing countries receiving such assistance have a plan for improving their economies?
2. How might the debt-for-nature program promote the goals of the Convention on Biological Diversity?

References

How debt-for-nature swaps protect tropical forests. The Nature Conservancy. http://www.nature.org/ourinitiatives/regions/centralamerica/guatemala/guatemala-debt-for-nature-swap-is-a-win-for-tropical-forest-conservation.xml.

Lacey, M. 2006. U.S. to cut Guatemala's debt for not cutting trees. *New York Times*, October 2. http://www.nytimes.com/2006/10/02/world/americas/02conserve.html.

U.S.-Brazil debt for nature swap to protect forests. August 12, 2010. http://www.bbc.co.uk/news/world-latin-america-10958695.

chapter 18 REVIEW

In this chapter, we examined the state of the world's biodiversity. We learned that the genetic diversity of many wild and domesticated populations has declined substantially over the past century. In addition, the species diversity of most major taxonomic groups has also declined, with large proportions of birds, mammals, and amphibians being threatened or near-threatened. These declines in species diversity also lead to declines in the intrinsic and instrumental values of ecosystems. The causes underlying these declines in diversity are wide-ranging and may include any combination of habitat loss, intrusion of exotic species, overharvesting, pollution, and climate change. While legislation to reverse these declines has focused on single species, conservation efforts have applied the concepts of metapopulations, island biogeography, and biosphere reserves to protect large areas of habitat and thereby protect large ecosystems.

Key Terms

Threatened species (IUCN)
Near-threatened species
Least concern species
Intrinsic value
Instrumental value
Provision
Native species
Exotic species
Alien species
Invasive species
Lacey Act
Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)
Red List
Marine Mammal Protection Act
Endangered species
Threatened species (U.S.)
Convention on Biological Diversity
Edge habitat
Biosphere reserve

Learning Objectives Revisited

Module 59 The Sixth Mass Extinction

- **Explain the global decline in the genetic diversity of wild species.**

  Declines in the abundance of individuals in a population can lead to reductions in genetic diversity that cause inbreeding depression. Inbreeding depression can cause offspring to inherit two copies of a harmful mutation and experience reduced survival and reproduction.

- **Discuss the global decline in the genetic diversity of domesticated species.**

  Humans have bred a wide variety of domesticated plants and animals, but in recent decades farmers have focused on the most productive varieties and many of the other varieties have disappeared over time. Such reductions in genetic diversity limit the options available to respond to new diseases or changing environmental conditions.

- **Identify the patterns of global decline in species diversity.**

  Of the estimated 10 million species on Earth, only about 50,000 have been assessed to determine whether their populations are increasing, stable, or declining. In examining those groups with the most complete data, scientists have found that every group has a substantial percentage of species that are threatened or near-threatened.

- **Explain the values of ecosystems and the global declines in ecosystem function.**

  Ecosystems can have intrinsic values, which are independent of any benefit to humans, or they can have instrumental values, which provide a benefit to humans and can be assigned a monetary value. Instrumental values include provisions, regulating services, support systems, resilience, and cultural services. Recent assessments of ecosystem function have found that more than half of those assessed are either declining or used at a rate that cannot be sustained.

Module 60 Causes of declining biodiversity

- **Discuss how habitat loss can lead to declines in species diversity.**

  The loss of habitat means that fewer individuals can be sustained in the habitat that remains. Smaller populations can then suffer from inbreeding depression. A reduction in habitat can also prevent the normal migration of species to important seasonal habitats and cause increased interactions with other species that have negative effects.

- **Explain how the movement of exotic species affects biodiversity.**

  Exotic species are those that are moved to new parts of the world where they are not native. Some of these species spread rapidly in their new locations and cause the demise of native species either as competitors, predators, herbivores, or pathogens.

- **Describe how overharvesting causes declines in populations and species.**

  Overharvesting plants and animals at rates that exceed the production of new individuals can cause population declines and even extinctions. Many of these extinctions have occurred due to unregulated harvesting in the past. However, in most parts of the world, governments have imposed harvest regulations to ensure that harvests occur in a sustainable manner.

- **Understand how pollution reduces populations and biodiversity.**

  Some pollutants can have direct lethal effects on species. Many other pollutants, however, can have sublethal effects that prevent or inhibit reproduction or alter ecosystems in ways that indirectly harm species.

- **Identify how climate change affects species diversity.**

  Climate change has the potential to alter the distribution of environmental conditions around the world. When conditions change and species are unable to move to more hospitable conditions, scientists predict that these species will either decline in abundance or go extinct.

Module 61 The Conservation of Biodiversity

- **Identify legislation that focuses on protecting single species.**

  The primary pieces of legislation in the United States to protect species are the Marine Mammal Protection Act and the Endangered Species Act. Internationally, nations created the Convention on Biological Diversity in order to conserve biodiversity, to use biodiversity sustainably, and to share equitably the benefits that emerge from the commercial use of biodiversity.

- **Discuss conservation efforts that focus on protecting entire ecosystems.**

  There has been a continual increase in the amount of aquatic and terrestrial habitats that have been protected around the world. When preserving such habitats, scientists consider the size, shape, and connectedness of these habitats as well as the presence of edge habitats. They have also incorporated the need to balance human use and habitat protection by designing biosphere reserves.

Chapter 18 AP® Environmental Science Practice Exam

Section 1: Multiple-Choice Questions

Choose the best answer for questions 1–11.

1. Which is a cause of declining global biodiversity?
   I. Pollution
   II. Habitat loss
   III. Overharvesting

   (a) I
   (b) I and II
   (c) I and III
   (d) II and III
   (e) I, II, and III

2. Which statement about global biodiversity is correct?
   (a) Species diversity is decreasing but genetic diversity is increasing.
   (b) Species diversity is decreasing and genetic diversity is decreasing.
   (c) Species diversity is increasing but genetic diversity is decreasing.
   (d) Declines in genetic diversity are occurring in wild plants but not in crop plants.
   (e) Declines in genetic diversity are occurring in crop plants but not in wild plants.

3. Which group of animals is declining in species diversity around the world?
   I. Fish and amphibians
   II. Birds and reptiles
   III. Mammals

   (a) I
   (b) I and II
   (c) I and III
   (d) II and III
   (e) I, II, and III

4. Which of the following species was historically overharvested?
   (a) Brown-headed cowbird
   (b) Honeybee
   (c) Kudzu vine
   (d) Dodo bird
   (e) Zebra mussel

5. Which statement is NOT correct regarding the genetic diversity of livestock?
   (a) The use of only the most productive breeds improves genetic diversity.
   (b) Livestock come from very few species.
   (c) The genetic diversity of livestock has declined during the past century.
   (d) Different breeds are adapted to different climatic conditions.
   (e) Different breeds are adapted to resist different diseases.

6. Which statement is NOT correct about invasive exotic species?
   (a) Their populations grow rapidly.
   (b) They often have no major predators or herbivores.
   (c) Most introduced species become established in new regions.
   (d) A well-known invasive exotic plant is the kudzu vine.
   (e) A well-known invasive exotic animal is the zebra mussel.

7. Which is an example of the single-species approach to conservation?
   I. The Endangered Species Act
   II. The Marine Mammal Protection Act
   III. The Biosphere Reserve

   (a) I
   (b) I and II
   (c) I and III
   (d) II and III
   (e) I, II, and III

8. Which is NOT an example of how the Endangered Species Act can affect human activities?
   (a) It has been used to prevent new construction.
   (b) It has prevented logging in particular areas.
   (c) It prevents the killing of listed species.
   (d) It prevents the trade of any parts of listed species.
   (e) It prevents human use of biosphere reserves.

9. Which principle of island biogeography is NOT correct?
   (a) A larger protected area should contain more species.
   (b) Protected areas that are closer together should contain more species.
   (c) National parks can be thought of as islands of biodiversity.
   (d) A larger protected area will have fewer habitats.
   (e) Marine reserves can be thought of as islands of biodiversity.

10. In a biosphere reserve
   (a) sustainable agriculture and tourism are permitted in different zones.
   (b) human activities are allowed throughout the reserve.
   (c) human activities are restricted to the central core of the reserve.
   (d) no human activities are permitted in a biosphere reserve.
   (e) sustainable agriculture is permitted, but tourism is not.

11. Which statement is correct regarding swapping debt for nature?
   (a) Protecting land and water is typically not expensive.
   (b) Developing countries can pay part of their debt by investing in their own environment.
   (c) Developing countries pay their debt to the United States by investing in U.S. national parks.
   (d) Having a plan to improve the economy of a developing country is not important.
   (e) The only expense of protecting biodiversity is the purchase of an area.

Section 2: Free-Response Questions

Write your answer to each part clearly. Support your answers with relevant information and examples. Where calculations are required, show your work.

1. The conservation of biodiversity is an international problem.
   (a) Name and describe one U.S. law that is intended to prevent the extinction of species. (4 points)
   (b) Name and describe one international treaty that is intended to prevent the extinction of species. (4 points)
   (c) Explain the benefits of taking an ecosystem approach, as opposed to a single-species approach, to conserving biodiversity. (2 points)

2. Tropical rainforests are home to a tremendous diversity of species. You have been asked to develop a plan to protect this diversity.
   (a) Describe the advantages and disadvantages of protecting a single large area versus several small areas. (2 points)
   (b) How might increasing the amount of edge habitat affect species that typically live deep in the forest? (3 points)
   (c) Discuss the merits of preserving individual species that are threatened and endangered versus preserving the function of the ecosystem. (3 points)
   (d) Describe three characteristics of organisms that would make them particularly vulnerable to extinction. (2 points)