CHAPTER

18

Conservation of Biodiversity
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).

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.

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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 ha (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 critical wildlife habitats continue today. In 2009, the Obama administration set aside 58 million ha (more than 200,000 square miles) of Alaska coastline and waters as critical habitat for polar bears. This does not prevent activities such as gas and oil drilling, but it does mean that potential impacts on polar bears must now be considered when such activities are proposed in this area. From 2006 to 2009, President George W. Bush designated a total of 95 million ha (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 ha (90 million acres) of these marine habitats were set aside as the Papahanaumokuakea 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 activity has caused a decline in this diversity. The anthropogenic causes of declining diversity are wide ranging. Although Hawaii has only 1.3 million residents, 7 million tourists visit each year. Both individuals and commercial 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 to be removed from the shorelines and coral reefs, and efforts are also 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 through the creation of marine reserves is a relatively new activity for governments, but the idea is gaining ground. In the Galápagos Islands, where, as we discussed in Chapter 5, different species of finch inspired Charles Darwin, 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. As more countries develop marine reserves, we have to make sure these areas are large enough to ensure long-term protection of local species and consider how each new reserve is positioned relative to other reserves so that individuals may be 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. These are exciting times that demonstrate that there is a great potential for conserving biodiversity in the twenty-first century.

Sources: Bush creates world’s biggest ocean preserve, MSNBC, June 16, 2006, http://www.msnbc.msn.com/id/13300363/;

**KEY IDEAS**

The conservation of biodiversity is a continuous challenge in a world that is increasingly affected by human population growth and development. After reading this chapter you should be able to

- understand how genetic diversity, species diversity, and ecosystem function are changing over time.
- identify the causes of declining biodiversity.
- describe the single-species approach to conserving biodiversity including the major laws that protect species.
- explain the ecosystem approach to conserving biodiversity and how size, shape, and connectedness affect the number of species that will be protected.

18.1  We are in the midst of a sixth mass extinction

As we have seen, protecting the biodiversity of individuals, species, and ecosystems is important because the biodiversity of the world provides a number of instrumental and intrinsic values to humans. Instrumental values include provisions such as food, medicine, and building materials; regulating services such as the ability of plants to remove human-added CO₂ from the atmosphere; and support services such as the pollination of agricultural crops. Intrinsic values provide no direct benefit to people but are simply the belief that individuals, species, and ecosystems are inherently valuable in themselves and that we have an obligation to preserve them. Given the importance of biodiversity, scientists are increasingly concerned about its rapid decline. In Chapter 5, we noted that the world has experienced five major extinctions during the past 500 million years and that we are currently experiencing a sixth major
extinction event. In scientific terms, an **extinction** occurs when the last member of a species dies. Scientists estimate that the world is currently experiencing approximately 50,000 species extinctions per year, amounting to 0.5 percent of the world’s species each year. One unique aspect of this sixth mass extinction is that it is happening over a relatively short period of time and is the first to occur since humans have been present on Earth. Indeed, the rate of decline has been 100 to 1,000 times faster 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. Another unique feature is that the current mass extinction has a human cause. In this section, we will examine the patterns of declining genetic diversity, species diversity, and ecosystem function.

**18.1. Global Declines in the Genetic Diversity of Wild Organisms**

At the lowest level of complexity, environmental scientists are concerned about conserving genetic diversity. One reason for this is that populations with low genetic diversity are not well suited to surviving environmental change. In addition, populations with low genetic diversity are prone to **inbreeding depression**. **Inbreeding depression** occurs when individuals with similar genotypes—typically relatives—breed with each other and produce off-spring that have an impaired ability to survive and reproduce. This impaired ability occurs when each parent carries one copy of a harmful mutation in his or her genome. When the parents breed, some of their offspring receive two copies of the harmful mutation and, as a result, have poor chances of survival and later reproduction. High genetic diversity ensures that a wider range of genotypes are present, which reduces the probability that an offspring will receive a harmful mutation from both parents. In addition, high genetic diversity improves the probability of surviving future change in the environment. This occurs because high genetic diversity produces a wide range of phenotypes that survive and reproduce under different environmental conditions.
Figure 18.1 Decline 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.

Some declines in genetic diversity have natural causes. Cheetahs (*Acinonyx jubatus*), 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 Chapter 6). Other declines in genetic diversity have human causes. For example, the panther, also known as a mountain lion or cougar, once ranged over much of North America. Because this predator could be a threat to humans and domestic livestock, efforts to eradicate it became intense as human populations grew. At the same time, much of the panther’s habitat disappeared as humans settled the land and increased agricultural activities. One subspecies, known as the Florida panther, once roamed throughout the southeastern United States (FIGURE 18.1). Because of hunting and habitat destruction, the population of the Florida panther shrank to only a small group in south Florida. This led to inbreeding since this group was too far away from other panther populations, such as a group in Texas, with which it could breed. This inbreeding caused a number of harmful effects, including heart defects and a high proportion of morphologically abnormal sperm. When this lack of genetic diversity caused the Florida panther population to decline even further—down to a total of 20 to 30 animals in 1995—scientists released 8 panthers from Texas into the remaining Florida habitat. This effort to add genetic diversity to the Florida subspecies and reduce the problems associated with inbreeding
was a success. Today, the Florida panther population is estimated at 80 to 100 individuals.

18.1. Global Declines in the Genetic Diversity of Crops and Livestock

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 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 to survive local climates. This wide variety of characteristics, which is underlain by a great deal of genetic variation, could be used for 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 endangered, meaning they are 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 (FIGURE 18.2).
Figure 18.2  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.

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 18.3). This facility was built into the side of a frozen mountain 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 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 2010, more than 430,000 seed varieties had already been sent to Svalbard for long-term storage.

Figure 18.3 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.

18.1. Global Declines in Species Diversity

To understand the current loss of biodiversity, we will begin by looking 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. *Threatened* species 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. 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 18.4** shows the most recent data for those species that are not yet extinct.

**FIGURE 18.4** 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.]

Since the year 1500, nearly 10,000 bird species have existed and 133 have become extinct. Today, 21 percent are threatened or near-threatened. Among the 800 species
of birds living in the United States, nearly one-third of them 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, 79 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 6,200 species of amphibians, 39 species are extinct. However, a recent assessment of amphibian populations suggests that the number of extinctions may accelerate soon in the coming decades. Among the approximately 4,000 species for which reliable data exist, 49 percent are either threatened or near-threatened. This means that nearly 2,000 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, of the species that have been assessed so far, 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.

18.1. Global Declines in Ecosystem Function

As we discussed in Chapter 3, ecosystems provide valuable services to humans, including both instrumental values and intrinsic values. These services include items that humans use directly such as lumber, food crops, and prescription drugs. They also include support systems such as pollinating many crops and filtering drinking water to reduce contaminants and pathogens. These services are critically important to humans.

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 2006, scientists from around the world examined the current state of various ecosystem functions, including food, clean water, pollination, water purification, and nutrient cycling. Of 24 different
ecosystem functions, 15 were found to be in decline. If we want to improve ecosystem functions, we need to improve the fate of the species and ecosystems that provide these services.

CHECKPOINT

- Why should we be concerned about inbreeding?
- What are the reasons for the declining genetic diversity of domesticated plants and animals?
- What are some of the challenges associated with understanding which species are threatened with extinction?

18.2 Declining biodiversity has many causes

Declines in biodiversity are happening around the globe. In Science Applied “How Should We Prioritize the Protection of Biodiversity?” on page 144 we discussed biodiversity hotspots, threatened areas that are rich in biodiversity. The need to protect biodiversity, however, exists far beyond these hotspots because the threats to biodiversity exist throughout the world. In Chapter 5, we discussed the basics of population and community ecology. In this chapter we build on these basics to understand how habitat loss, intrusion of alien species, overharvesting, pollution, and climate change all affect our efforts to conserve biodiversity.

18.2. Habitat Loss

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, restricting their distribution to a limited geographic area suitable only for a small population. The alteration of a habitat, such as the removal of trees or the damming of streams that give the habitat its distinctive characteristics, 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 Pacific northwestern region of the United States and
British Columbia (see FIGURE 10.1). 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 18.5). 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 18.6 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 was logged during the 1700s and 1800s for lumber and was cleared for agriculture. In recent decades, forested land has been increasing, although the new forests have often been planted by humans and have a lower diversity of species than the original forest. 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 allow their forested areas to increase.
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.]

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 existed in the United States during the 1600s, from 1998 to 2004 the amount of freshwater wetland habitat increased. This overall growth occurred due to large increases in the Great Lakes region despite a decline in coastal wetlands in the eastern United States and the Gulf of Mexico because of growing human populations that require more roads, homes, and businesses.
Figure 18.7 Changing coral reefs. The percentage of coral that remains alive in coral reefs has declined sharply in the Caribbean since 1977. [After Global Biodiversity Outlook 2, Convention on Biological Diversity, 2006.]

In marine systems, there has been a sharp decline in the amount of living coral in the Caribbean Sea, as shown in **FIGURE 18.7**, from a high of 50 percent live coral in the 1970s to a mere 10 percent by 2002. 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. 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 other
species of birds (FIGURE 18.8). In this way the cowbird tricks forest birds into raising its offspring, which takes food away from the other 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.

Figure 18.8  The brown-headed cowbird. (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).

18.2. Alien Species

Native species are species that live in their historical range, typically where they have lived for thousands or millions of years. In contrast, alien species, also known as exotic 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, such as rats stowing away in shipping containers and often ending up far from their original
port, sometimes on oceanic islands. Since many oceanic islands have never had rats or other ground predators, there had never been any natural selection against nesting on the ground. As a result, numerous island bird species 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 fungi that have killed nearly all American elm (*Ulmus americana*) and American chestnut (*Castanea dentata*) trees in eastern North America and a protist that has caused avian malaria and driven many species of Hawaiian birds to extinction. Other species are moved intentionally, such as exotic plants that are sold in greenhouses for houseplants and outdoor landscape plants, or animals that are sold as pets or to game ranches that raise exotic species of large mammals for hunting.

Not all alien species are a threat to biodiversity. In many cases, the alien species live in their new surroundings and have no negative effect on the native species. In other cases, the alien species rapidly increase in population size and cause harmful effects on native species. When alien 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 control their population, often have no natural enemies in the regions where they are introduced. Two of the best known examples of invasive alien 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 18.9a**). Kudzu currently covers approximately 2.5 million ha (7 million acres) in the United States.
The zebra mussel is native to the Black Sea and the Caspian Sea in Asia. Over the years, large cargo ships that traveled in these seas unloaded their cargo in Asian ports 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, so they pumped the ballast water 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 (FIGURE 18.9b).

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 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 in 2010 it was rapidly approaching a canal where the Mississippi River connects to Lake Michigan. 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 the water when startled by passing boats (FIGURE 18.9c). 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 alien 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 the Nordic countries of Iceland, Sweden, Finland, Norway, and Denmark. As FIGURE 18.10 shows, during the past one hundred years, these countries have experienced a steady increase of nearly 1,700 alien species in terrestrial, freshwater, and marine ecosystems combined. A number of efforts are currently being used to reduce the introduction of invasive 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.
Figure 18.10 Exotic species. Over the decades, there has been a steady increase in the number of alien species. This example shows the number of alien species recorded in three environments from the Nordic countries of Iceland, Sweden, Finland, Norway, and Denmark. [After Global Biodiversity Outlook 2, Convention on Biological Diversity, 2006.]

18.2. Overharvesting

[Notes/Highlighting]
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.

Hunting, fishing, and other forms of harvesting are the most direct human influences on wild populations of plants and animals. Most populations 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 its evolutionary history ([FIGURE 18.11](#)). 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 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. This timing suggests 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 declined dramatically, including the American bison (*Bison bison*). 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. 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 (*Ectopistes migratorius*) was once one of the most abundant species of birds in North America. Population estimates range from 3 to 5 million 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 in these areas. With such high densities, market hunters could shoot or net the birds in very large numbers and fill train cars with 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 from 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 of 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, oversight is conducted by the U.S. Fish and Wildlife Service.

![Philippine forest turtle](image)

**Figure 18.12** *Philippine forest turtle.* 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.

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 18.12). 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.

Sometimes even when trade in a particular species is legal, it can pose a potential long-term threat to species persistence. In the American southwest, for example, there is a growing movement to reduce water use by replacing grassy 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.

### 18.2. Pollution

**[Notes/Highlighting]**

In Chapter 14 and Chapter 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 named the Deepwater Horizon exploded, causing a massive release of oil that lasted for several months. This release of oil, from a platform owned by BP, 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.

### 18.2. Climate Change

**[Notes/Highlighting]**

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 how it will affect 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. (You can see this biome on the map in FIGURE 4.17.) 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.

CHECKPOINT

- How does habitat loss influence species extinction?
- Compare and contrast the primary causes of biodiversity loss; which one do you think is most important?
- Why are alien species a threat to biodiversity?

18.3 The conservation of biodiversity often focuses on single species

Given the large number of factors that can cause a reduction in biodiversity, it is important that we consider how to protect and increase biodiversity. There are two general approaches to conserving biodiversity: the single-species approach and the ecosystem approach.

The single-species approach to conserving biodiversity focuses our efforts on one species at a time. When a species declines to a status of threatened or endangered, the natural response is to encourage a population rebound by improving the conditions in which it exists. This might be accomplished by providing additional habitat or reducing the presence of a contaminant that is causing impaired 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 today numbers more than 300 birds. Programs such as these are a major function of zoos and aquariums around the world.

18.3. Conservation Legislation

The single-species approach to conservation formed the foundation for the passage of the Marine Mammal Protection Act in 1972 and the Endangered Species Act in 1973 in the United States. The Marine Mammal Protection Act was passed in response to declining populations of many marine mammals, including polar bears, sea otters (*Enhydra lutris*), manatees (*Trichechus manatus*), and California sea lions (*Zalophus californianus*) (*FIGURE 18.13*). The 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.

![Protected marine mammals](image)

**Figure 18.13** 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.

![Bald eagle hatchlings](image)

**Figure 18.14** Bald eagle hatchlings. 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.

The Endangered Species Act, which has been amended several times since its initial passage in 1973, implements the international CITES agreement. The act authorizes the U.S. Fish and Wildlife Service to determine which species can be listed as threatened or endangered and prohibits the harming of such species, including prohibitions on the trade of listed species, their fur, or their body parts. The act also authorizes the government to purchase habitat that is critical to the conservation of
threatened and endangered 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. Today, the species that have been listed as threatened or endangered include 201 invertebrate animals, 381 vertebrate animals, and 795 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 that they have been taken off the endangered species list, including the bald eagle (FIGURE 18.14), the American alligator (*Alligator mississippiensis*), 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 restricts certain human activities in areas where listed species live. For example, it has prevented or altered some construction projects to accommodate threatened or endangered species. Organizations whose activities are restricted often pit the protection of listed species against the jobs of people in the region. In the 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. Although automation had caused a decline in the number of logging jobs in the preceding several decades, many loggers perceived the Endangered Species Act as a further threat to their livelihood. They denounced the act for placing more value on the spotted owl than 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 for the spotted owl, as well as the many other species depending on old-growth forest. 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](https://www.cbd.int), 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.

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.

**CHECKPOINT**

- What is the single-species approach to conserving biodiversity?
- What makes the Endangered Species Act controversial? Why is it important to legislate species protection?
- In what ways is biodiversity protection an international issue?

**18.4** The conservation of biodiversity sometimes focuses on protecting entire ecosystems
Since the 1960s, there has been a large increase in the amount of land that is under various types of protection throughout the world. [After Global Biodiversity Outlook 2, Convention on Biological Diversity, 2006.]

Awareness of a sixth mass extinction in which humans have played a major role has brought a growing interest in the ecosystem approach to conserving biodiversity, which 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 worldwide since 1960. **FIGURE 18.15** shows changes in the amount of protected land worldwide since 1900.

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.

**18.4. 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 industrial parks (FIGURE 18.16). 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. 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.

### 18.4. Biosphere Reserves

In Chapter 10 we saw that managing national parks and other protected areas so they serve multiple users can be a challenge. On the one hand we want to make places of great natural beauty available to everyone. Yet 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 18.17** shows the different zones in a model 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.
Biosphere reserves ideally consist of core areas that have minimal human impact and outer zones that have increasing levels of human impacts. 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. Currently there are 564 biosphere reserves worldwide—47 in the United States—with a total of 109 nations participating. 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 species and more than 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 18.18).
Figure 18.18  **Big Bend National Park.** The entire park, located in southwest Texas, serves as a low-impact core area of the Big Bend biosphere reserve.

**CHECKPOINT**

- How does island biogeography help us decide how to protect species?
- What are the different ways that reserves can be designed?
- What is a biosphere reserve and how does it help preserve biodiversity?

**WORKING TOWARD SUSTAINABILITY**

**Swapping Debt for Nature**

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

In 1984, Thomas Lovejoy from the World Wildlife Fund came up with an idea to help protect large areas of land and 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. The developing countries were slowly repaying their loans with interest, but some countries had fallen so far behind on these payments that debtor nations doubted that 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 debtor nations could use their position to motivate investment in biodiversity conservation. 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 the country. The debtor government then makes 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 annual 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 (FIGURE 18.19). 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*).
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. 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.

To date, the United States has used the debt-for-nature swap in 12 countries to protect tropical forests 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 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.
KEY IDEAS REVISITED

- Understand how genetic diversity, species diversity, and ecosystem function are changing over time.

The genetic diversity of both wild and domesticated species is declining, as is the species diversity for all groups of organisms that have been assessed so far. Because species help to determine the function of ecosystems, declines in species diversity have, in turn, caused losses in ecosystem services.

- Identify the causes of declining biodiversity.

Because each species relies on a particular habitat, a major cause of declining biodiversity is the loss of habitat. Additional causes include overharvesting, legal and illegal trading in plants and animals, introductions of alien species, pollution, and climate change.

- Describe the single-species approach to conserving biodiversity including the major laws that protect species.

The single-species approach to conserving biodiversity focuses on saving one species at a time, often by using laws such as the Marine Mammal Protection Act and the Endangered Species Act.

- Explain the ecosystem approach to conserving biodiversity and how size, shape, and connectedness affect the number of species that will be protected.

The ecosystem approach to conserving biodiversity focuses on protecting not just a particular species of interest, but entire communities of organisms that live in an ecosystem. This is the goal of the biosphere reserve program of the United Nations. In protecting areas, we have to consider the theories of island biogeography and metapopulations because we can protect more biodiversity if we save larger areas of habitat that are close enough to each other to allow organisms to disperse.

PREPARING FOR THE AP EXAM

MULTIPLE-CHOICE QUESTIONS

[Notes/Highlighting]

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) Honeybees
   - (c) Kudzu vine
   - (d) Dodo bird
   - (e) Zebra mussel

5. Which statement is incorrect 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 different diseases.

6. Which statement is incorrect about invasive alien species?
   - (a) Their populations grow rapidly.
   - (b) They often have no major predators or herbivores.
   - (c) They are often competitively inferior.
   - (d) A well-known invasive alien plant is the kudzu vine.
   - (e) A well-known invasive alien 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

   [Answer Field]

8. Which principle of island biogeography is *incorrectly* applied to protecting areas of land or water?
   - (a) A larger protected area should contain more species.
   - (b) Protected areas that are closer to each other 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.

   [Answer Field]

9. Which statement *correctly* reflects the idea of 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.

   [Answer Field]

10. 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.
FREE-RESPONSE QUESTIONS

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. As a result, you need 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)

MEASURING YOUR IMPACT

1. How Large Is Your Home? One of the major worldwide threats to biodiversity is habitat loss, including the loss of forests as the result of logging. Given that the demand for lumber drives much of the market for logging, consider how you and your family might influence the demand for lumber.
   • (a) From 1970 to 2010, the average size of a house in the United States has doubled while the average size of a family has been reduced by half. Based on this information, how much more space per person does a modern house have?
   • (b) The average house today uses the lumber from 50 trees. If homes were built to be half the size, and there are approximately 400,000 new homes built each year, how many trees could be saved?
   • (c) Rather than demolishing an older house and building a new one, many homeowners have chosen to move an older house to a new location. This effectively recycles the older house. There are currently 50,000 homes moved
annually. Assuming that the average house uses the lumber from 50 trees, how many trees are saved when houses are moved rather than demolished?