CONCEPTS OF BIOLOGY

Chapter 21 CONSERVATION AND BIODIVERSITY

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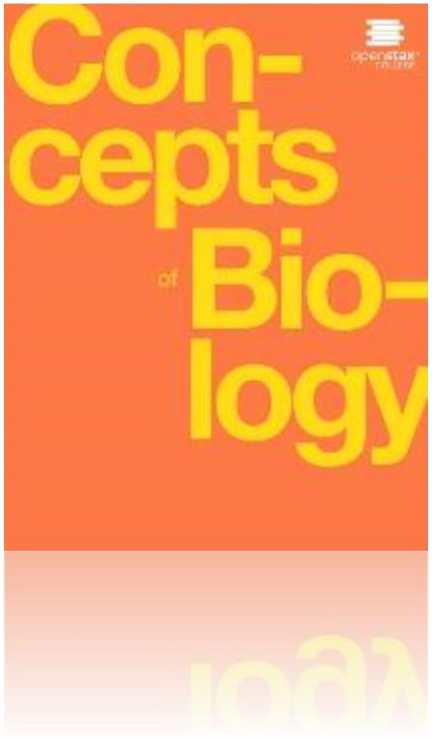

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INTRODUCTION

- Biologists estimate that species extinctions are currently 500–1000 times the rate seen previously in Earth's history when there were no unusual geological or climatic events occurring.
- The current high rates will cause a large decline in the biodiversity (the diversity of species) of the planet in the next century or two.
- The majority of extinctions will be of species that science has not yet even described.
- Most of these species currently live in tropical rainforests like those of the Amazon basin.
- Between 1970 and 2011, almost 20% of the Amazon rainforest was lost (Figure 21.1).
- This increased loss of biodiversity is almost entirely a result of human activities.

FIGURE 21.1 AMAZON RAINFOREST

Habitat destruction through deforestation, especially of tropical rainforests as seen in this satellite view of Amazon rainforests in Brazil, is a major cause of the current decline in biodiversity. (credit: modification of work by Jesse Allen and Robert Simmon, NASA Earth Observatory)

IMPORTANCE OF BIODIVERSITY (21.1)

- **Biodiversity** is the variety of a biological system, traditionally measured as the number of species and the number of individuals in each of these species (relative abundance).
    - Now it also applies to genes, biochemistry and ecosystems.
- The loss of a particular individual species, may seem unimportant, but the current accelerated extinction rate means the loss of tens of thousands of species within our lifetimes. Much of this loss is occurring in tropical rainforests (Figure 21.2).
- Biologists recognize that human populations are embedded in ecosystems and are dependent on them, just as is every other species on the planet.
- Our ecosystems provide our food, medications and clean water.

FIGURE 21.2 HIGH BIODIVERSITY

This tropical lowland rainforest in Madagascar is an example of a high biodiversity habitat. This particular location is protected within a national forest, yet only 10 percent of the original coastal lowland forest remains, and research suggests half the original biodiversity has been lost. (credit: Frank Vassen)

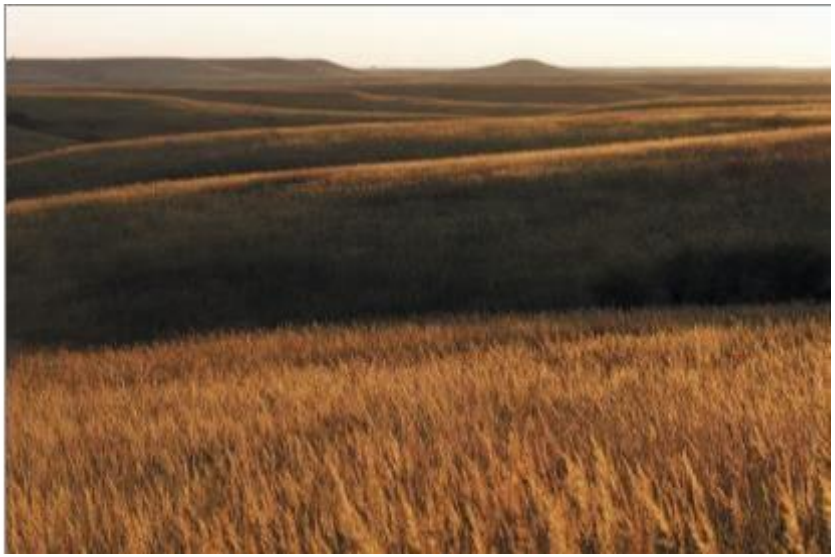
TYPES OF BIODIVERSITY 1 OF 2 (21.1)

- A common meaning of biodiversity is simply the number of species in a location or on Earth.
- More sophisticated measures of diversity take into account the relative abundances of species.
- **Genetic diversity** is the variety of genes and alleles in a species or other taxonomic group or ecosystem.
    - A species' future potential for adaptation depends on the genetic diversity held in the genomes of the individuals in populations that make up the species.
- **Chemical diversity** is the variety of metabolic compounds in an ecosystem.
    - Species with different genetic makeups produce different assortments of chemicals in their cells.

TYPES OF BIODIVERSITY 2 OF 2 (21.1)

- Chemical diversity is important for humans because of the potential uses for these chemicals, such as medications.
    - At present, it is far cheaper to discover compounds made by an organism than to imagine them and then synthesize them in a laboratory.
- **Ecosystem diversity** is the number of different ecosystems on Earth or in a geographical area.
    - Whole ecosystems can disappear even if some of the species might survive by adapting to other ecosystems.
    - An example of a largely extinct ecosystem in North America is the prairie ecosystem (Figure 21.3).
    - Their agricultural soils are now being depleted unless they are maintained artificially at greater expense.

FIGURE 21.3 VARIETY OF ECOSYSTEMS



The variety of ecosystems on Earth—from coral reef to prairie—enables a great diversity of species to exist. (credit “coral reef”: modification of work by Jim Maragos, USFWS; credit: “prairie”: modification of work by Jim Minnerath, USFWS)

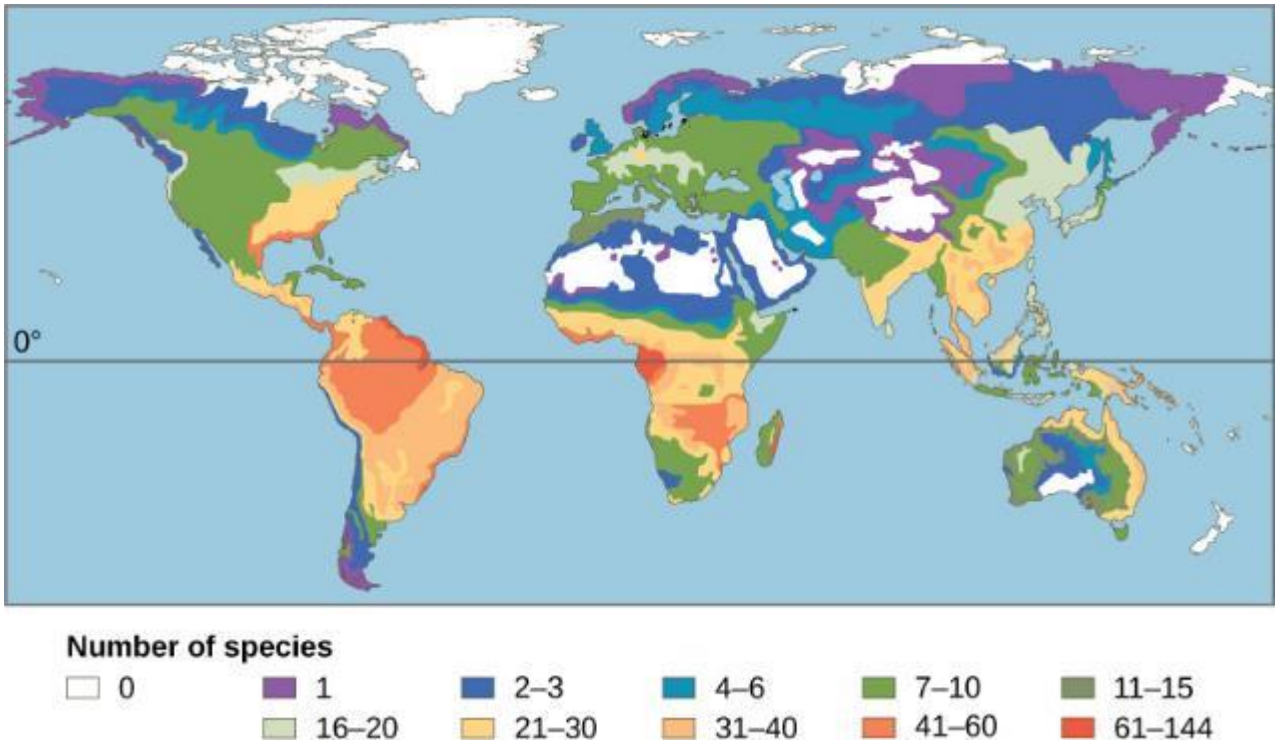
CURRENT SPECIES DIVERSITY (21.1)

- Despite considerable effort, knowledge of the species that inhabit the planet is limited.
- A recent estimate suggests that the total number of named eukaryote species is about 1.5 million species. This likely accounts for less than 20% of the total number of eukaryote species.
- Estimates of numbers of prokaryotic species are largely guesses, but biologists agree that science has only just begun to catalog their diversity.
- There are various initiatives to catalog described species and the internet is facilitating that effort.
- The task, however, is becoming increasingly impossible over time as extinction removes species from Earth faster than they can be described.

PATTERNS OF BIODIVERSITY (21.1)

- Biodiversity is not evenly distributed on the planet.
- **Endemic species** are found in only one location. Endemics with highly restricted distributions are particularly vulnerable to extinction.
- Biodiversity in almost every taxonomic group increases as latitude declines. In other words, biodiversity increases closer to the equator (Figure 21.4).
- It is not yet clear why biodiversity increases closer to the equator, but hypotheses include:
    - the greater age of the ecosystems near the equator
    - the greater energy the tropics receive from the sun
    - the complexity of tropical ecosystems may promote speciation by increasing the **habitat heterogeneity** (number of ecological niches), in the tropics

FIGURE 21.4 BIODIVERSITY BY LATITUDE



This map illustrates the number of amphibian species across the globe and shows the trend toward higher biodiversity at lower latitudes. A similar pattern is observed for most taxonomic groups.

IMPORTANCE OF BIODIVERSITY (21.1)
HUMAN HEALTH

- Many medications are derived from natural chemicals made by a diverse group of organisms.
- Many plants produce **secondary plant compounds**, which are toxins used to protect the plant from insects and other animals that eat them. Some of these secondary plant compounds also work as human medicines.
- Examples of medicines derived from plant compounds include aspirin, codeine, digoxin, atropine, and vincristine (Figure 21.5).
- Antibiotics, which are responsible for extraordinary improvements in health and lifespans in developed countries, are largely derived from fungi and bacteria.
- In recent years, animal venoms and poisons have excited intense research for their medicinal potential.
- Aside from representing billions of dollars in profits, these medications improve people's lives.

FIGURE 21.5 PLANT DERIVED MEDICINE

Catharanthus roseus, the Madagascar periwinkle, has various medicinal properties. Among other uses, it is a source of vincristine, a drug used in the treatment of lymphomas. (credit: Forest and Kim Starr)

IMPORTANCE OF BIODIVERSITY (21.1) AGRICULTURAL 1 OF 2

- Since the beginning of human agriculture more than 10,000 years ago, human groups have been breeding and selecting crop varieties.
- Every plant, animal, and fungus that has been cultivated by humans has been bred from original wild ancestor species into diverse varieties.
- Resistance to disease is a chief benefit to maintaining crop biodiversity.
- The ability to create new crop varieties relies on the diversity of varieties available and the availability of wild forms related to the crop plant.
- Since the 1920s, government agriculture departments have maintained seed banks of crop varieties as a way to maintain crop diversity (Figure 21.6)
- Although crops are largely under our control, our ability to grow them depends on the biodiversity of the ecosystems in which they are grown.

FIGURE 21.6 SVALBARD GLOBAL SEED VAULT

The Svalbard Global Seed Vault is a storage facility for seeds of Earth's diverse crops. (credit: Mari Tefre, Svalbard Global Seed Vault)

In 2008, the Svalbard Global seed Vault, located on Spitsbergen island, Norway, began storing seeds from around the world as a backup system to the regional seed banks.

IMPORTANCE OF BIODIVERSITY (21.1) AGRICULTURAL 2 OF 2

- Ecosystem services are valuable conditions or processes that are carried out by an ecosystem. Key ecosystem services related to food production are soils, plant pollinators and crop pest control:
  - Most soils contain a huge diversity of organisms that maintain nutrient cycles (breaking down organic matter into nutrient compounds that crops need for growth).
  - It is estimated that honey bee pollination within the U.S. brings in $1.6 billion per year; other pollinators contribute up to $6.7 billion. Honeybee populations in North America have been suffering large losses caused by a syndrome known as **colony collapse disorder.**
  - Humans compete for their food with crop pests. Pesticides control these competitors, but these are costly and lose their effectiveness over time as pests adapt. They also kill non-pest species and beneficial insects like honeybees, and risk the health of agricultural workers and consumers.

IMPORTANCE OF BIODIVERSITY (21.1)
WILD FOOD SOURCES

- Humans obtain food resources from wild populations, primarily wild fish populations.
- For about one billion people, aquatic resources provide the main source of animal protein.
- But since 1990, production from global fisheries has declined.
- Despite considerable effort, few fisheries on Earth are managed sustainability.
- The ultimate outcome could clearly be the loss of aquatic systems as food sources.

FISHERIES CONCEPT IN ACTION

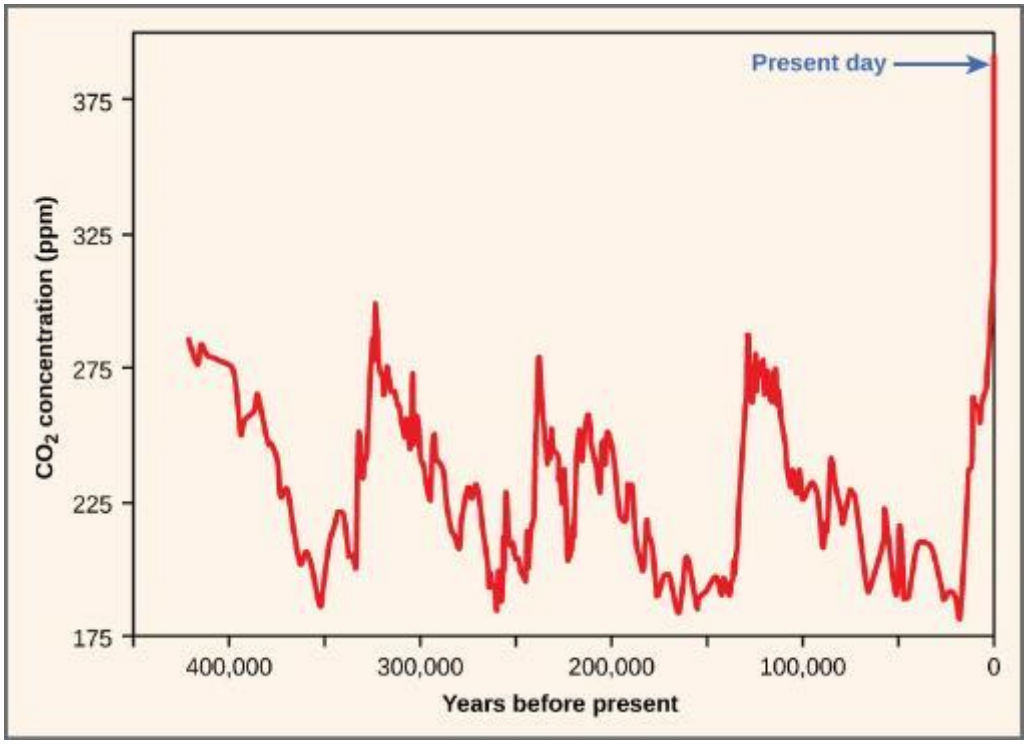
Visit this website to view a brief video discussing a study of declining fisheries.

Link to Video

THREATS TO BIODIVERSITY (21.2)

- The core threat to biodiversity on the planet is the combination of human population growth and the resources used by that population.
- The three greatest proximate threats to biodiversity are habitat loss, overharvesting, and introduction of exotic species.
- The first two of these are a direct result of human population growth and resource use. The third results from increased mobility and trade.
- A fourth major cause of extinction, human-caused climate change, has not yet had a large impact, but it is predicted to become significant during this century (Figure 21.7).

FIGURE 21.7 CLIMATE CHANGE



Atmospheric carbon dioxide levels fluctuate in a cyclical manner. However, the burning of fossil fuels in recent history has caused a dramatic increase in the levels of carbon dioxide in the Earth's atmosphere, which have now reached levels never before seen on Earth. Scientists predict that the addition of this "greenhouse gas" to the atmosphere is resulting in climate change that will significantly impact biodiversity in the coming century.

HABITAT LOSS 1 OF 2 (21.2)

- Humans rely on technology to modify their environment and replace certain functions that were once performed by the natural ecosystem.
- Other species cannot do this. Elimination of their habitat will kill the individuals in the species.
- Human destruction of habitats (the part of the ecosystem required by a particular species) accelerated in the latter half of the twentieth century.
- For example, both Borneo and Sumatra (areas in Malaysia) have lost about half of their forests.
    - The forests are removed for timber and to plant palm oil plantations (Figure 21.8).
    - These areas are home to many species, including some that are critically endangered or endangered.

FIGURE 21.8 OIL PALM PLANTATION

An oil palm plantation in Sabah province Borneo, Malaysia, replaces native forest habitat that a variety of species depended on to live. (credit: Lian Pin Koh)

HABITAT LOSS 2 OF 2 (21.2)

- Habitat destruction can affect ecosystems other than forests.
- Rivers and streams are important ecosystems and are frequently the target of habitat modification through building and from damming or water removal.
- Many fish species in the United States, especially rare species or species with restricted distributions, have seen declines caused by river damming and habitat loss.
- Species of amphibians that must carry out parts of their life cycles in both aquatic and terrestrial habitats are at greater risk of population declines and extinction because of the increased likelihood that one of their habitats or access between them will be lost.
    - This is of particular concern because amphibians have been declining in numbers and going extinct more rapidly than many other groups.

OVERHARVESTING 1 OF 2 (21.2)

- Overharvesting is a serious threat to many species, but particularly to aquatic species.
- There are many examples of regulated fisheries monitored by fisheries scientists that have nevertheless collapsed.
    - The western Atlantic cod fishery is the most spectacular recent collapse. While it was a hugely productive fishery for 400 years, the introduction of modern factory trawlers in the 1980s and the pressure on the fishery led to it becoming unsustainable.
- Most fisheries are managed as a common resource, available to anyone willing to fish, even when the fishing territory lies within a country's territorial waters.
- Common resources are subject to an economic pressure known as the **tragedy of the commons**, which states that resources held in common will inevitably be over-exploited.

HABITAT MAP CONCEPT IN ACTION

Explore a U.S. Fish & Wildlife Service interactive map of critical habitat for endangered and threatened species in the United States.

To begin, select “Visit the online mapper.”

Launch Interactive

OVERHARVESTING 2 OF 2 (21.2)

- For the most part, fishery extinction is not equivalent to biological extinction—the last fish of a species is rarely fished out of the ocean.
- But there are some instances in which true extinction is a possibility. For example, whales and sharks are often slow-growing and/or have restricted distributions.
- **Bush meat** is the generic term used for wild animals killed for food. Hunting is practiced throughout the world, but hunting practices, particularly in equatorial Africa and parts of Asia, are believed to threaten several species with extinction.
    - Species threatened by the bush meat trade are mostly mammals including many monkeys and the great apes living in the Congo basin.

OCEAN CONCEPT IN ACTION

View a brief video discussing the role of marine ecosystems in supporting human welfare and the decline of ocean ecosystems.

Link to Video

EXOTIC SPECIES 1 OF 3 (21.2)

- **Exotic species** are species that have been intentionally or unintentionally introduced by humans into an ecosystem in which they did not evolve.
- Some species are especially successful in the new ecosystem and undergo dramatic population increases. They reset the ecological conditions in the new environment, threatening the species that exist there. Then the exotic species becomes an invasive species.
- Lakes and islands are particularly vulnerable to extinction threats from introduced species.
    - In Lake Victoria, the intentional introduction of the Nile perch was largely responsible for the extinction of about 200 species of cichlids.
    - The accidental introduction of the brown tree snake (Figure 21.9) from the Solomon Islands to Guam in 1950 has led to the extinction of 3 species of birds and 3-5 species of reptiles.

FIGURE 21.9 AN EXOTIC SNAKE IN GUAM

The brown tree snake, *Boiga irregularis*, is an exotic species that has caused numerous extinctions on the island of Guam since its accidental introduction in 1950. (credit: NPS)

GLOBAL DATABASE CONCEPT IN ACTION

Explore this interactive global database of exotic or invasive species.

Launch Interactive

EXOTIC SPECIES 2 OF 3 (21.2)

- Many introductions of aquatic species, both marine and freshwater, have occurred when ships have dumped ballast water taken on at a port of origin into waters at a destination port.
    - The zebra mussel was introduced to the Great Lakes from Europe prior to 1988 in ship ballast. They have cost the industry millions of dollars in clean up costs to maintain water intakes and other facilities. The mussels have also altered the ecology of the lakes dramatically.

EXOTIC SPECIES 3 OF 3 (21.2)

- Invading exotic species can also be disease organisms.
  - The global decline in amphibian species recognized in the 1990s is, in some part, caused by a fungus which causes the disease **chytridiomycosis** (Figure 21.10). The fungus is native to Africa and may have been spread by transport of a commonly used laboratory and pet species of frog.
  - Early evidence suggests that another fungus introduced from Europe is responsible for **white-nose syndrome**, which infects cave-hibernating bats in eastern North America (Figure 21.11). The disease has decimated bat populations and threatens extinction of several species.

FIGURE 21.10 CHYTRIDIOMYCOSIS

This Limosa harlequin frog (*Atelopus limosus*), an endangered species from Panama, died from a fungal disease called chytridiomycosis. The red lesions are symptomatic of the disease. (credit: Brian Gratwicke)

FIGURE 21.11 WHITE-NOSE SYNDROME

This little brown bat in Greeley Mine, Vermont, March 26, 2009, was found to have white-nose syndrome. (credit: modification of work by Marvin Moriarty, USFWS)

CLIMATE CHANGE 1 OF 3 (21.2)

- Climate change, and the warming trend presently underway caused by human activities, is recognized as a major extinction threat, particularly when combined with other threats such as habitat loss.
- Warming of the earth is due to the emission of greenhouse gases, primarily carbon dioxide and methane, into the atmosphere caused by the burning of fossil fuels and deforestation.
    - These gases decrease the degree to which Earth is able to radiate heat that enters the atmosphere from the Sun.
- Much of our current understanding of the trends come from predictions made by computer models.
- Scientists generally agree the present warming trend is caused by humans and some of the likely effects include dramatic and dangerous climate changes in the coming decades.
- Scientists disagree about the likely magnitude of the effects on extinction rates, with estimates ranging from 15 to 40 percent of species committed to extinction by 2050.

CLIMATE CHANGE 2 OF 3 (21.2)

- Scientists agree that climate change will alter regional climates, including rainfall and snowfall patterns, making habitats less hospitable to the species living in them.
- The warming trend will shift colder climates toward the north and south poles, forcing species to move with their adapted climate norms, but also to face habitat gaps along the way.
- Range shifts are already being observed.
    - On average, European bird species ranges have moved 91 km (56.5 mi) northward.
    - Range shifts have also been observed in plants, butterflies, other insects, freshwater fishes, reptiles, amphibians, and mammals.

CLIMATE CHANGE 3 OF 3 (21.2)

- Climate gradients will also move up mountains, eventually crowding species higher in altitude and eliminating the habitat for those species adapted to the highest elevations.
- The rate of warming appears to be accelerated in the arctic, threatening polar bear populations that require sea ice to hunt seals during the winter months.
    - A trend of decreasing sea ice coverage has occurred. The rate of decline observed in recent years is far greater than previously predicted by climate models (Figure 21.12).
- Global warming will also raise ocean levels due to meltwater from glaciers. Shorelines will be inundated, reducing island size, which will have an effect on some species.

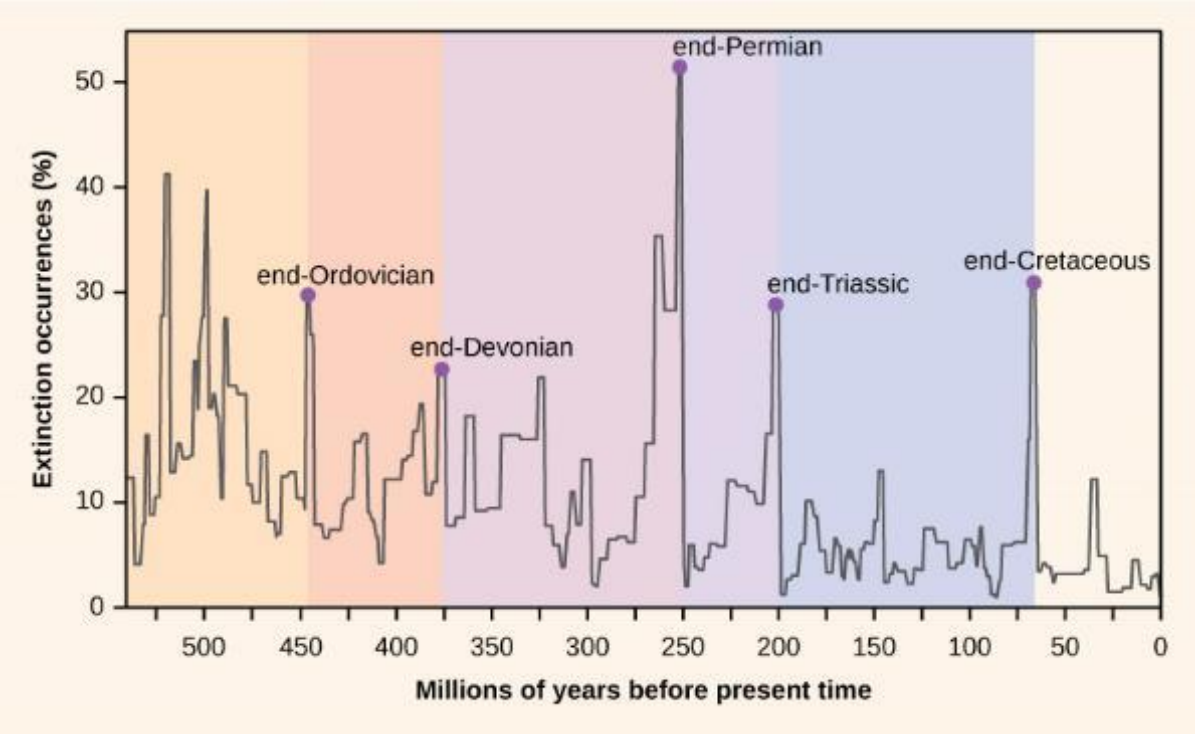
FIGURE 21.12
GLACIER RETREAT DUE TO GLOBAL WARMING

The effect of global warming can be seen in the continuing retreat of Grinnell Glacier. The mean annual temperature in Glacier National Park has increased 1.33°C since 1900. The loss of a glacier results in the loss of summer meltwaters, sharply reducing seasonal water supplies and severely affecting local ecosystems. (credit: USGS, GNP Archives)

PRESERVING BIODIVERSITY (21.3)
CHANGE IN BIODIVERSITY THROUGH TIME

- The number of species on the planet is the result of an equilibrium of two evolutionary processes that are ongoing: speciation and extinction. Throughout history, these two processes have fluctuated to a greater or lesser extent (Figure 21.13).
    - When speciation rates overtake extinction rates, the number of species will increase. When extinction rates overtake speciation rates, the number of species will decrease.
- Paleontologists have identified five strata in the fossil record that appear to show sudden and dramatic losses in biodiversity. These are called **mass extinctions,** and involve more than half of the species disappearing from the fossil record.
    - The most recent extinction in geological time, about 65 million years ago, saw the disappearance of the dinosaurs and many other species.

FIGURE 21.13 MASS EXTINCTIONS



Extinction intensity as reflected in the fossil record has fluctuated throughout Earth's history. Sudden and dramatic losses of biodiversity, called mass extinctions, have occurred five times.

RECENT AND CURRENT EXTINCTION RATES (21.3)

- A sixth, or Holocene, mass extinction has mostly to do with the activities of *Homo sapiens*. Most of these coincide with the expansion of the European colonies since the 1500s.
- The dodo bird, which went extinct around 1662, lived on an island in the Indian Ocean. It was hunted for its meat by sailors and was easy prey because it would approach people without fear.
    - Introduced pigs, rats, and dogs brought to the island by European ships also killed dodo young and eggs (Figure 21.14).
- Steller's sea cow became extinct in 1768; it was related to the manatee and probably once lived along the northwest coast of North America.
    - Steller's sea cow was discovered by Europeans in 1741, and it was hunted for meat and oil.
    - A total of 27 years elapsed between the sea cow's first contact with Europeans and extinction of the species.
- These are only a couple of examples of the recorded extinctions in the past 500 years.

FIGURE 21.14 DODO BIRD

The dodo bird was hunted to extinction around 1662. (credit: Ed Uthman, taken in Natural History Museum, London, England)

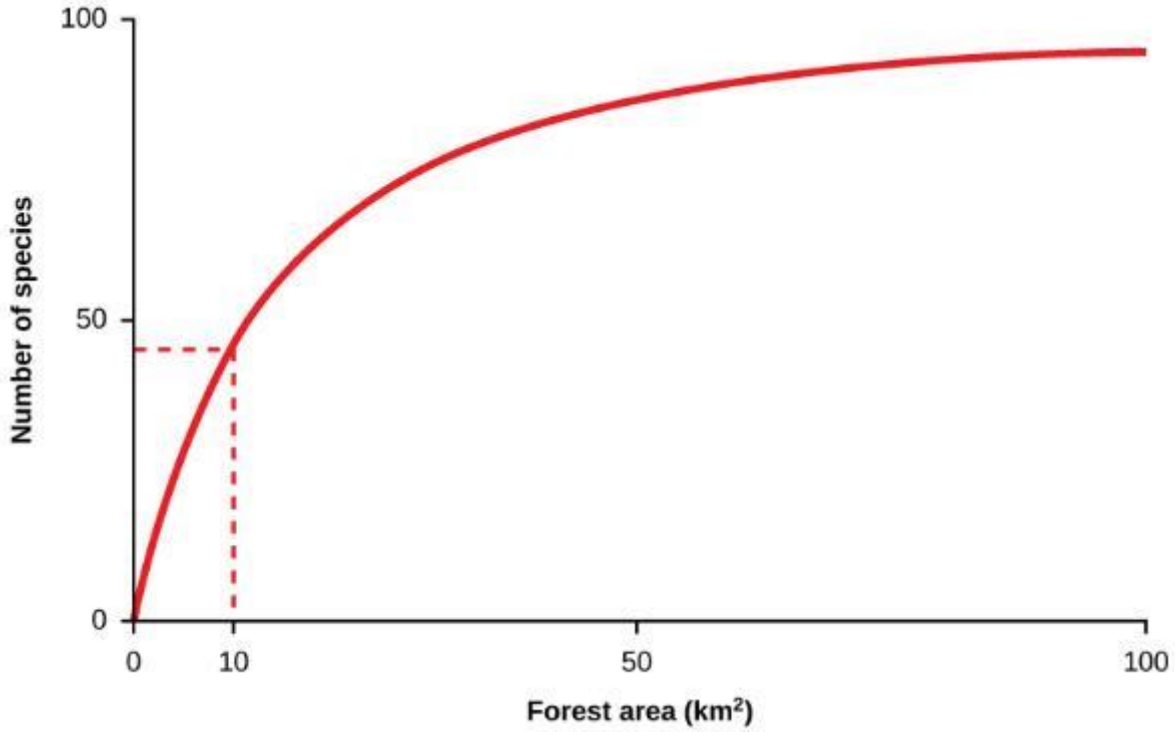
ESTIMATES OF PRESENT DAY EXTINCTION RATES 1 OF 2 (21.3)

- Estimates of extinction rates are hampered by the fact that most extinctions are probably happening without being observed.
- The **background extinction rate** is estimated to be about 1 per million species years (E/MSY).
    - One “species year” is one species in existence for one year.
    - One million species years could be one species persisting for one million years, or a million species persisting for one year.
- One contemporary extinction-rate estimate uses the extinctions in the written record since the year 1500.
    - For birds alone, this method yields an estimate of 26 E/MSY, almost three times the background rate. This number is likely underestimated, however, and is most likely nearer 100 E/MSY.

ESTIMATES OF PRESENT DAY EXTINCTION RATES 2 OF 2 (21.3)

- A second approach to estimating present-time extinction rates is to correlate species loss with habitat loss. It is based on measuring forest-area loss and understanding species–area relationships.
  - The **species-area relationship** is the rate at which new species are seen when the area surveyed is increased (Figure 21.15).
  - Estimates of extinction rates based on habitat loss and species–area relationships have suggested that with about 90 percent of habitat loss an expected 50 percent of species would become extinct.
  - Species–area estimates have led to estimates of present-day species extinction rates of about 1000 E/MSY and higher. This is 1000 times the background rate.

FIGURE 21.15 SPECIES-AREA CURVE



A typical species-area curve shows the cumulative number of species found as more and more area is sampled. The curve has also been interpreted to show the effect on species numbers of destroying habitat; a reduction in habitat of 90 percent from 100 km^2 to 10 km^2 reduces the number of species supported by about 50 percent.

EXTINCTION CONCEPT IN ACTION

Go to this website for an interactive exploration of endangered and extinct species, their ecosystems, and the causes of their endangerment or extinction.

Launch Interactive

CONSERVATION OF BIODIVERSITY (21.3)

- The threats to biodiversity at the genetic, species, and ecosystem levels have been recognized for some time.
- In the United States, the first national park with land set aside to remain in a wilderness state was Yellowstone Park in 1890.
- However, attempts to preserve nature for various reasons have occurred for centuries.

CHANGING HUMAN BEHAVIOR 1 OF 2 (21.3)

- Legislation, including international treaties, national laws and state laws, has been enacted to protect species throughout the world.
- The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) Treaty came into force in 1975.
    - It provides a legal framework for preventing “listed” species from being transported across nations’ borders, thus protecting them from being caught or killed.
- Within many countries there are laws that protect endangered species and that regulate hunting and fishing.
    - In the United States, the Endangered Species Act was enacted in 1973. It requires the U.S. Fish & Wildlife Service to develop a management plan to protect at-risk species.
    - The Migratory Bird Treaty Act is an agreement between the U.S. and Canada that was signed into law in 1918. The Act makes it illegal to disturb or kill over 800 protected species of birds or to distribute their parts (feathers).

CHANGING HUMAN BEHAVIOR 2 OF 2 (21.3)

- Global warming is expected to be a major driver of biodiversity loss. Many governments are concerned about the effects on their economies and food resources.
    - Since greenhouse gas emissions do not respect national boundaries, the effort to curb them is an international one.
- The Kyoto Protocol, an international agreement that came out of the United Nations Framework Convention on Climate Change that committed countries to reducing greenhouse gas emissions by 2012, was ratified by some countries, but spurned by others.
    - The United States and China did not ratify.
- The non-profit, non-governmental sector also plays a large role in conservation effort both in North America and around the world.
    - The Nature Conservancy purchases land and protects it in an attempt to set up preserves for ecosystems

CONSERVATION IN PRESERVES 1 OF 3 (21.3)

- Establishment of wildlife and ecosystem preserves is one of the key tools in conservation efforts (Figure 21.16).
- A **preserve** is an area of land set aside with varying degrees of protection for the organisms that exist within the boundaries of the preserve.
- In 2003, the IUCN World Parks Congress estimated that 11.5 percent of Earth's land surface was covered by preserves of various kinds.
    - This only represents 9 out of 14 recognized major biomes and research has shown that 12 percent of all species live outside preserves.

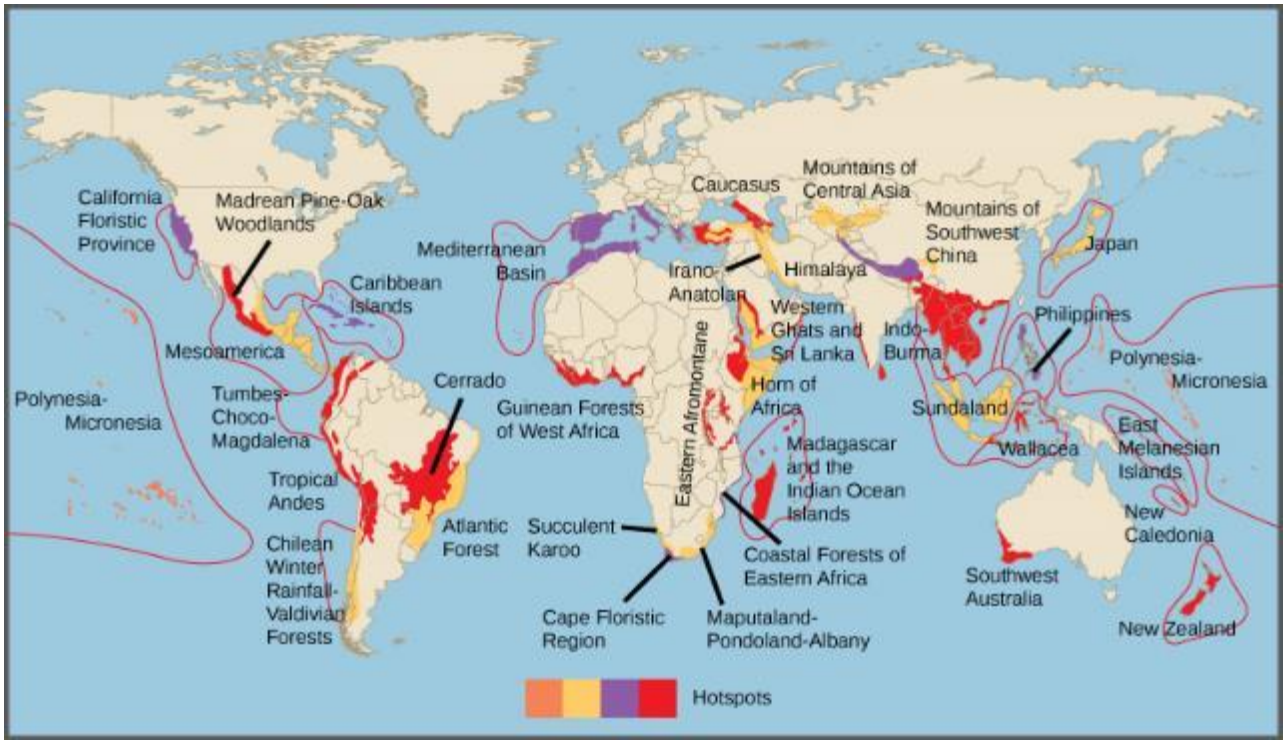
FIGURE 21.16 A NATIONAL PARK

National parks, such as Grand Teton National Park in Wyoming, help conserve biodiversity. (credit: Don DeBold)

CONSERVATION IN PRESERVES 2 OF 3 (21.3)

- A **biodiversity hotspot** is a conservation concept developed by Norman Myers in 1988. Hotspots are geographical areas that contain high numbers of endemic species.
    - The purpose of the concept was to identify important locations on the planet for conservation efforts.
    - There are now 34 biodiversity hotspots (Figure 21.17).
- There has been extensive research into optimal preserve designs for maintaining biodiversity.
- Large preserves are better because they:
    - support more species
    - have more core area of optimal habitat for individual species
    - have more niches to support more species
    - attract more species because they can be found and reached more easily.

FIGURE 21.17 BIODIVERSITY HOTSPOTS



Conservation International has identified 34 biodiversity hotspots. Although these cover only 2.3 percent of the Earth's surface, 42 percent of the terrestrial vertebrate species and 50 percent of the world's plants are endemic to those hotspots.

CONSERVATION IN PRESERVES 3 OF 3 (21.3)

- Preserves perform better when there are partially protected buffer zones around them of suboptimal habitat.
- There are a variety of regulations related to the use of a preserve. These include timber extraction, mineral extraction, regulated hunting, human habitation, and nondestructive human recreation.
    - Many of the decisions to include these other uses are made based on political pressures rather than conservation considerations.
- Climate change will create inevitable problems with the location of preserves as the species within them migrate to higher latitudes as the habitat of the preserve becomes less favorable.

PROTECTED AREAS CONCEPT IN ACTION

Check out this interactive global data system of protected areas. Review data about specific protected areas by location or study statistics on protected areas by country or region.

Launch Interactive

HABITAT RESTORATION (21.3)

- Habitat restoration holds considerable promise as a mechanism for maintaining or restoring biodiversity.
- Reintroducing wolves, a top predator, to Yellowstone National Park in 1995 led to dramatic changes in the ecosystem that increased biodiversity (Figure 21.18).
    - In this habitat, the wolf is a keystone species, meaning a species that is instrumental in maintaining diversity within an ecosystem.
- Other large-scale restoration experiments underway involve dam removal.
    - In the United States, since the mid-1980s, many aging dams are being considered for removal rather than replacement because of shifting beliefs about the ecological value of free-flowing rivers.
    - The restoration of naturally fluctuating water levels by removing dams often leads to increased fish diversity and improved water quality.

FIGURE 21.18 THE GIBBON WOLF

This photograph shows the Gibbon wolf pack in Yellowstone National Park, March 1, 2007. Wolves have been identified as a keystone species. (credit: Doug Smith, NPS)

THE ROLE OF ZOOS AND CAPTIVE BREEDING (21.3)

- Zoos have sought to play a role in conservation efforts both through captive breeding programs and education (Figure 21.19).
- It has been recognized that, except in some specific targeted cases, captive breeding programs for endangered species are inefficient and often prone to failure when the species are reintroduced to the wild.
- Zoo facilities are far too limited to contemplate captive breeding programs for the numbers of species that are now at risk.
- Education is a potential positive impact of zoos on conservation efforts, particularly given the global trend to urbanization and the reduction in contact between people and wildlife.

FIGURE 21.19 GOLDEN LION TAMARIN

Zoos and captive breeding programs help preserve many endangered species, such as this golden lion tamarin. (credit: Garrett Ziegler)

VOCABULARY

- Biodiversity
- Chemical diversity
- Genetic diversity
- Ecosystem diversity
- Endemic species
- Habitat heterogeneity
- Secondary plant compound
- Colony collapse disorder
- Tragedy of the commons
- Bush meat
- Exotic species
- Chytridiomycosis
- White nose syndrome
- Mass extinction
- Background extinction rate
- Species-area relationship
- Preserve
- Biological hotspot