Overview: Striking Gold

- Scientists have named and described 1.8 million species
- Biologists estimate 10–200 million species exist on Earth
- Tropical forests contain some of the greatest concentrations of species and are being destroyed at an alarming rate
- Humans are rapidly pushing many species toward extinction

Concept 56.1: Human activities threaten Earth’s biodiversity

- Rates of species extinction are difficult to determine under natural conditions
- The high rate of species extinction is largely a result of ecosystem degradation by humans
- Humans are threatening Earth’s biodiversity

Conservation biology, which seeks to preserve life, integrates several fields
- Ecology
- Physiology
- Molecular biology
- Genetics
- Evolutionary biology

Genetic Diversity

- Genetic diversity comprises genetic variation within a population and between populations
Species Diversity

- Species diversity is the variety of species in an ecosystem or throughout the biosphere
- According to the U.S. Endangered Species Act
  - An endangered species is “in danger of becoming extinct throughout all or a significant portion of its range”
  - A threatened species is likely to become endangered in the foreseeable future

- Conservation biologists are concerned about species loss because of alarming statistics regarding extinction and biodiversity
- Globally, 12% of birds, 20% of mammals, and 32% of amphibians are threatened with extinction
- Extinction may be local or global

Ecosystem Diversity

- Human activity is reducing ecosystem diversity, the variety of ecosystems in the biosphere
- More than 50% of wetlands in the contiguous United States have been drained and converted to other ecosystems

- The local extinction of one species can have a negative impact on other species in an ecosystem
  - For example, flying foxes (bats) are important pollinators and seed dispersers in the Pacific Islands

Biodiversity and Human Welfare

- Human biophilia allows us to recognize the value of biodiversity for its own sake
- Species diversity brings humans practical benefits
Benefits of Species and Genetic Diversity

- Species related to agricultural crops can have important genetic qualities
  - For example, plant breeders bred virus-resistant commercial rice by crossing it with a wild population
- In the United States, 25% of prescriptions contain substances originally derived from plants
  - For example, the rosy periwinkle contains alkaloids that inhibit cancer growth

Ecosystem Services

- **Ecosystem services** encompass all the processes through which natural ecosystems and their species help sustain human life
- Some examples of ecosystem services
  - Purification of air and water
  - Detoxification and decomposition of wastes
  - Cycling of nutrients
  - Moderation of weather extremes

Threats to Biodiversity

- Most species loss can be traced to four major threats
  - Habitat destruction
  - Introduced species
  - Overharvesting
  - Global change

Habitat Loss

- Human alteration of habitat is the greatest threat to biodiversity throughout the biosphere
- In almost all cases, habitat fragmentation and destruction lead to loss of biodiversity
- For example
  - In Wisconsin, prairie occupies <0.1% of its original area
  - About 93% of coral reefs have been damaged by human activities
**Introduced Species**

- **Introduced species** are those that humans move from native locations to new geographic regions
- Without their native predators, parasites, and pathogens, introduced species may spread rapidly
- Introduced species that gain a foothold in a new habitat usually disrupt their adopted community

**Sometimes humans introduce species by accident**
- For example, the brown tree snake arrived in Guam as a cargo ship “stowaway” and led to extinction of some local species

**Humans have deliberately introduced some species with good intentions but disastrous effects**
- For example, kudzu was intentionally introduced to the southern United States

**Overharvesting**

- Overharvesting is human harvesting of wild plants or animals at rates exceeding the ability of populations of those species to rebound
- Large organisms with low reproductive rates are especially vulnerable to overharvesting
  - For example, elephant populations declined because of harvesting for ivory

**DNA analysis can help conservation biologists identify the source of illegally obtained animal products**
- For example, DNA from illegally harvested ivory can be used to trace the original population of elephants to within a few hundred kilometers
• Overfishing has decimated wild fish populations
  – For example, the North Atlantic bluefin tuna has decreased by 80% in ten years

Global Change
• Global change includes alterations in climate, atmospheric chemistry, and broad ecological systems
• Acid precipitation contains sulfuric acid and nitric acid from the burning of wood and fossil fuels

• Air pollution from one region can result in acid precipitation downwind
  – For example, industrial pollution in the midwestern United States caused acid rain in eastern Canada in the 1960s
• Acid precipitation kills fish and other lake-dwelling organisms
• Environmental regulations have helped to decrease acid precipitation
  – For example, sulfur dioxide emissions in the United States decreased 31% between 1993 and 2002

Concept 56.2: Population conservation focuses on population size, genetic diversity, and critical habitat

• Biologists focusing on conservation at the population and species levels follow two main approaches
  – The small-population approach
  – The declining-population approach

Small-Population Approach
• The small-population approach studies processes that can make small populations become extinct
The Extinction Vortex: Evolutionary Implications of Small Population Size

- A small population is prone to inbreeding and genetic drift that draw it down an **extinction vortex**
- The key factor driving the extinction vortex is loss of the genetic variation necessary to enable evolutionary responses to environmental change
- Small populations and low genetic diversity do not always lead to extinction

**Case Study: The Greater Prairie Chicken and the Extinction Vortex**

- Populations of the greater prairie chicken were fragmented by agriculture and later found to exhibit decreased fertility
- To test the extinction vortex hypothesis, scientists imported genetic variation by transplanting birds from larger populations
- The declining population rebounded, confirming that low genetic variation had been causing an extinction vortex

**Minimum Viable Population Size**

- **Minimum viable population (MVP)** is the minimum population size at which a species can survive
- The MVP depends on factors that affect a population’s chances for survival over a particular time

**Effective Population Size**

- A meaningful estimate of MVP requires determining the **effective population size**, which is based on the population’s breeding potential
Effective population size $N_e$ is estimated by

$$N_e = \frac{4N_f N_m}{N_f + N_m}$$

where $N_f$ and $N_m$ are the number of females and the number of males, respectively, that breed successfully.

Viability analysis is used to predict a population’s chances for survival over a particular time interval.

The Yellowstone grizzly population has low genetic variability compared with other grizzly populations.

Introducing individuals from other populations would increase the numbers and genetic variation.

Case Study: Analysis of Grizzly Bear Populations

One of the first population viability analyses was conducted as part of a long-term study of grizzly bears in Yellowstone National Park.

It is estimated that a population of 100 bears would have a 95% chance of surviving about 200 years.

This grizzly population is about 400, but the $N_e$ is about 100.

Declining-Population Approach

The declining-population approach

- Focuses on threatened and endangered populations that show a downward trend, regardless of population size
- Emphasizes the environmental factors that caused a population to decline

Steps for Analysis and Intervention

The declining-population approach involves several steps

1. Confirm that the population is in decline
2. Study the species’ natural history
3. Develop hypotheses for all possible causes of decline
4. Test the hypotheses in order of likeliness
5. Apply the results of the diagnosis to manage for recovery

Case Study: Decline of the Red-Cockaded Woodpecker

- Red-cockaded woodpeckers require living trees in mature pine forests
- These woodpeckers require forests with little undergrowth
- Logging, agriculture, and fire suppression have reduced suitable habitat
• They have a complex social structure where one breeding pair has up to four “helper” individuals
• Individuals often have a better chance of reproducing by helping and waiting for an available cavity, instead of excavating new cavities

Weighing Conflicting Demands
• Conserving species often requires resolving conflicts between habitat needs of endangered species and human demands
• For example, in the U.S. Pacific Northwest, habitat preservation for many species is at odds with timber and mining industries
• Managing habitat for one species might have positive or negative effects on other species

Concept 56.3: Landscape and regional conservation help sustain biodiversity
• Conservation biology has attempted to sustain the biodiversity of entire communities, ecosystems, and landscapes
• Ecosystem management is part of landscape ecology, which seeks to make biodiversity conservation part of land-use planning

Landscape Structure and Biodiversity
• The structure of a landscape can strongly influence biodiversity
**Fragmentation and Edges**

- The boundaries, or edges, between ecosystems are defining features of landscapes.
- Some species take advantage of edge communities to access resources from both adjacent areas.

**Corridors That Connect Habitat Fragments**

- A **movement corridor** is a narrow strip of quality habitat connecting otherwise isolated patches.
- Movement corridors promote dispersal and help sustain populations.
- In areas of heavy human use, artificial corridors are sometimes constructed.

**Establishing Protected Areas**

- Conservation biologists apply understanding of ecological dynamics in establishing protected areas to slow the loss of biodiversity.

**Preserving Biodiversity Hot Spots**

- A **biodiversity hot spot** is a relatively small area with a great concentration of endemic species and many endangered and threatened species.
- Biodiversity hot spots are good choices for nature reserves, but identifying them is not always easy.

- Designation of hot spots is often biased toward saving vertebrates and plants.
- Hot spots can change with climate change.
**Philosophy of Nature Reserves**

- Nature reserves are biodiversity islands in a sea of habitat degraded by human activity
- Nature reserves must consider disturbances as a functional component of all ecosystems

- An important question is whether to create fewer large reserves or more numerous small reserves
- One argument for large reserves is that large, far-ranging animals with low-density populations require extensive habitats
- Smaller reserves may be more realistic, and may slow the spread of disease throughout a population

**Zoned Reserves**

- The zoned reserve model recognizes that conservation often involves working in landscapes that are largely human dominated
- A zoned reserve includes relatively undisturbed areas and the modified areas that surround them and that serve as buffer zones
- Zoned reserves are often established as “conservation areas”
- Costa Rica has become a world leader in establishing zoned reserves

- Some zoned reserves in the Fiji islands are closed to fishing, which actually improves fishing success in nearby areas
- The United States has adopted a similar zoned reserve system with the Florida Keys National Marine Sanctuary
Concept 56.4: Earth is changing rapidly as a result of human actions

- The locations of preserves today may be unsuitable for their species in the future
- Human-caused changes in the environment include
  - Nutrient enrichment
  - Accumulations of toxins
  - Climate change
  - Ozone depletion

Nutrient Enrichment

- In addition to transporting nutrients from one location to another, humans have added new materials, some of them toxins, to ecosystems
- Agriculture leads to the depletion of nutrients in the soil
- Fertilizers add nitrogen and other nutrients to the agricultural ecosystem

Critical load is the amount of added nutrient that can be absorbed by plants without damaging ecosystem integrity
- Agricultural runoff and sewage lead to phytoplankton blooms in the Atlantic Ocean
- Decomposition of phytoplankton blooms causes "dead zones" due to low oxygen levels

Toxins in the Environment

- Humans release many toxic chemicals, including synthetics previously unknown to nature
- In some cases, harmful substances persist for long periods in an ecosystem
- Biological magnification concentrates toxins at higher trophic levels, where biomass is lower

PCBs and many pesticides such as DDT are subject to biological magnification in ecosystems
- Herring gulls of the Great Lakes lay eggs with PCB levels 5,000 times greater than in phytoplankton

In the 1960s Rachel Carson brought attention to the biomagnification of DDT in birds in her book *Silent Spring*
- DDT was banned in the United States in 1971
- Countries with malaria face a trade-off between killing mosquitoes (malarial vectors) and protecting other species
Greenhouse Gases and Global Warming

- One pressing problem caused by human activities is the rising level of atmospheric CO\textsubscript{2}

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\caption{Rising Atmospheric CO\textsubscript{2} Levels}
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Rising Atmospheric CO\textsubscript{2} Levels

- Due to burning of fossil fuels and other human activities such as deforestation, the concentration of atmospheric CO\textsubscript{2} has been steadily increasing
- C\textsubscript{3} plants (for example, wheat and soybeans) are more limited by CO\textsubscript{2} than C\textsubscript{4} plants (for example, corn)

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\caption{Rising Atmospheric CO\textsubscript{2} Levels}
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The Greenhouse Effect and Climate

- CO\textsubscript{2}, water vapor, and other greenhouse gases reflect infrared radiation back toward Earth; this is the greenhouse effect
- This effect is important for keeping Earth's surface at a habitable temperature
- Northern coniferous forests and tundra show the strongest effects of global warming
  - For example, in 2007 the extent of Arctic sea ice was the smallest on record
- A warming trend would also affect the geographic distribution of precipitation

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\caption{The Greenhouse Effect and Climate}
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- Global warming can be slowed by reducing energy needs and converting to renewable sources of energy
- Stabilizing CO\textsubscript{2} emissions will require an international effort
- Reduced deforestation would also decrease greenhouse gas emissions

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\caption{The Greenhouse Effect and Climate}
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Depletion of Atmospheric Ozone

- Life on Earth is protected from damaging effects of UV radiation by a protective layer of ozone molecules in the atmosphere
- Satellite studies suggest that the ozone layer has been gradually thinning since the mid-1970s

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\caption{Depletion of Atmospheric Ozone}
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- Destruction of atmospheric ozone results mainly from chlorofluorocarbons (CFCs) produced by human activity
- CFCs contain chlorine which reacts with ozone to make O\textsubscript{2}
- This decreases ozone in the atmosphere

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\caption{Depletion of Atmospheric Ozone}
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The ozone layer is thinnest over Antarctica and southern Australia, New Zealand, and South America. Ozone levels have decreased 2–10% at mid-latitudes during the past 20 years.

Ozone depletion causes DNA damage in plants and poorer phytoplankton growth. An international agreement signed in 1987 has resulted in a decrease in ozone depletion.

Skin cancer and UV

Concept 56.5: Sustainable development can improve the human condition while conserving biodiversity

- The concept of sustainability helps ecologists establish long-term conservation priorities

Sustainable Biosphere Initiative

- **Sustainable development** is development that meets the needs of people today without limiting the ability of future generations to meet their needs
- The goal of the Sustainable Biosphere Initiative is to define and acquire basic ecological information for responsible development, management, and conservation of Earth’s resources

Case Study: Sustainable Development in Costa Rica

- Costa Rica’s conservation of tropical biodiversity involves partnerships between the government, nongovernmental organizations (NGOs), and private citizens
- Human living conditions (infant mortality, life expectancy, literacy rate) in Costa Rica have improved along with ecological conservation