

Chapter 56

Conservation Biology and Restoration Ecology

Lecture Outline

Overview: Striking Gold

- Scientists have described and formally named about 1.8 million species of organisms.
 - Some biologists think that about 10 million more species currently exist.
 - Others estimate the number to be as high as 200 million.
- Some of the greatest concentrations of species are found in the tropics. Unfortunately, tropical forests are being cleared at an alarming rate.
- Throughout the biosphere, human activities are altering trophic structures, energy flow, chemical cycling, and natural disturbance.
 - The amount of human-altered land surface is approaching 50%, and humans use more than half of the accessible surface fresh water.
 - In the oceans, stocks of most major fisheries are shrinking because of overharvesting.
- Biology is the study of life. Two disciplines within biology seek to preserve life.
 1. **Conservation biology** integrates ecology, evolutionary biology, physiology, molecular biology, genetics, and behavioral ecology to conserve biological diversity at all levels.
 2. **Restoration ecology** applies ecological principles in an effort to return degraded ecosystems to conditions as similar as possible to their natural, predegraded state.

Concept 56.1 Human activities threaten Earth's biodiversity.

- Extinction is a natural phenomenon that has been occurring since life evolved on Earth.
- The current *rate* of extinction is what underlies the biodiversity crisis.

The three levels of biodiversity are genetic diversity, species diversity, and ecosystem diversity.

- Genetic diversity comprises not only the individual genetic variation *within* a population but also the genetic variation *between* populations that is often associated with adaptations to local conditions.
 - If a local population becomes extinct, then the entire population of that species has lost some of the genetic diversity that makes microevolution possible.
 - The loss of this diversity is detrimental to the overall adaptive prospects of the species.
- The loss of wild populations of plants also means the loss of genetic resources that could potentially be used to improve crop qualities, such as disease resistance.

- When grassy stunt virus infected rice (*Oryza sativa*), plant breeders screened 7,000 populations of rice and its wild relatives.
- They found resistance in only one population of a single relative, Indian rice (*Oryza nivara*), and bred the resistance into commercial rice varieties.
- Today, the original disease-resistant population has gone extinct in the wild.
- Species diversity is the variety of species in an ecosystem or throughout the entire biosphere.
 - Much of the discussion of the biodiversity crisis centers on species.
- The U.S. Endangered Species Act (ESA) defines an **endangered species** as one that is “in danger of extinction throughout all or a significant portion of its range,” and a **threatened species** as one likely to become endangered in the foreseeable future.
- Here are some reasons conservation biologists are concerned about species loss.
 - The International Union for Conservation of Natural Resources (IUCN) reports that 12% of nearly 10,000 known bird species and 20% of nearly 5,000 known mammal species are threatened with extinction.
 - The Center for Plant Conservation estimates that 200 of the 20,000 known plant species in the United States have become extinct since records have been kept, and another 730 are endangered or threatened.
 - About 20% of the known freshwater species of fish in the world have become extinct or are seriously threatened.
 - One of the largest rapid extinctions is the ongoing loss of freshwater fishes in East Africa’s Lake Victoria. About 200 of the more than 500 species of cichlids in the lake have been lost, mainly as a result of the introduction of the Nile perch in the 1960s.
 - Since 1900, 123 freshwater vertebrate and invertebrate species have become extinct in North America, and hundreds more are threatened. The extinction rate for North American freshwater fauna is about five times as high as that for terrestrial animals.
 - Of all known amphibian species, 32% are now either very near extinction or endangered.
- Extinction of species may be local, when a species is lost in one area but survives in an adjacent one; global extinction means that a species is lost from *all* its locales.
- Ecosystem diversity involves the variety of the biosphere’s ecosystems.
- The local extinction of one species, especially a keystone predator, can affect an entire community.
 - For example, bats called “flying foxes” are important pollinators and seed dispersers in the Pacific Islands, where they face severe hunting pressure.
 - Extinction of the bats will harm the native Samoan plants, 79% of which depend on the bats for pollination or seed dispersal.
- Some ecosystems are being altered at a rapid pace.
 - Within the contiguous United States, more than 50% of wetlands have been drained and converted to other ecosystems, primarily agricultural.
 - In California, Arizona, and New Mexico, 90% of native riparian communities have been affected by overgrazing, flood control, water diversions, lowering of water tables, and invasion by nonnative plants.

Biodiversity at all three levels is vital to human welfare.

- Why should we care about biodiversity?
- Perhaps the purest reason is what E. O. Wilson calls *biophilia*, our sense of connection to nature.

- The belief that other species are entitled to life is a pervasive theme of many religions and the basis of a moral argument for the preservation of biodiversity.
- Future human generations may be deprived of Earth's species richness.
- Biodiversity is a crucial natural resource: Species that are threatened could provide crops, fibers, and medicines for human use.
 - In the United States, 25% of all prescriptions dispensed from pharmacies contain substances originally derived from plants.
 - In the 1970s, alkaloids that inhibit two deadly cancers were extracted from the rosy periwinkle, a plant growing on the island of Madagascar.
- The loss of species also means the loss of genes.
- Each species has certain unique genes, and biodiversity represents the sum of all the genomes of all organisms on Earth.
- Such enormous genetic diversity has the potential for great human benefit.
 - The polymerase chain reaction is based on an enzyme extracted from thermophilic prokaryotes from hot springs.
 - Corporations are using DNA extracted from prokaryotes in hot springs and other extreme environments to mass-produce useful enzymes for new medicines, foods, petroleum substitutes, industrial chemicals, and other products.
- Because millions of species may become extinct before we even know about them, we will lose the valuable genetic potential held in their unique libraries of genes.
- Humans evolved in Earth's ecosystems, and we are finely adjusted to these systems.
- **Ecosystem services** encompass all the processes through which natural ecosystems and the species they contain help sustain human life on Earth. These services include:
 - Purification of air and water
 - Reduction of the severity of droughts and floods
 - Generation and preservation of fertile soils
 - Detoxification and decomposition of wastes
 - Pollination of crops and natural vegetation
 - Dispersal of seeds
 - Cycling of nutrients
 - Control of agricultural pests by natural enemies
 - Protection of shorelines from erosion
 - Protection from ultraviolet rays
- In a controversial 1997 article, ecologist Robert Costanza and his colleagues estimated the value of Earth's ecosystem services at \$33 trillion per year, nearly twice the gross national product of all the countries on Earth at that time.
- The functioning of ecosystems and, hence, their capacity to perform particular services are linked to biodiversity.

The three major threats to biodiversity are habitat loss, introduced species, and overexploitation.

- Human alteration of habitat is the single greatest threat to biodiversity throughout the biosphere.
 - Loss of habitat has been brought about by agriculture, urban development, forestry, mining, and pollution.

- Global warming is already altering habitats today, and its impact will increase.
- When no alternative habitat is available or when a species is unable to move, habitat loss may mean extinction.
- The IUCN states that destruction of physical habitat is responsible for the 73% of species designated extinct, endangered, vulnerable, or rare.
- Habitat destruction may occur over immense regions.
 - For instance, approximately 98% of the tropical dry forests of Central America and Mexico have been cut down.
 - Many natural landscapes have been broken up, fragmenting habitats into small patches.
 - Forest fragmentation is occurring at a rapid rate in tropical forests.
- In almost all cases, habitat fragmentation leads to species loss, since the smaller populations in habitat fragments have a higher probability of local extinction.
 - The prairies of southern Wisconsin now occupy less than 0.1% of the 800,000 hectares they covered when the Europeans arrived in North America.
 - Between 1948 and 1988, the remaining prairie remnants lost 8–60% of their plant species.
- Habitat loss is a major threat to marine biodiversity, especially on continental coasts and coral reefs.
 - About 93% of the world's coral reefs have been damaged by human activities.
 - At the present rate of destruction, 40–50% of the reefs, home to one-third of marine fish species, will be lost in the next 30–40 years.
- Aquatic habitat destruction and species loss also result from dams, reservoirs, channel modification, and flow regulation affecting most of the world's rivers.
 - By changing river depth and flow, more than 30 dams and locks built along the Mobile River basin in the southeastern United States helped drive more than 40 species of endemic mussels and snails extinct.
- **Introduced species**, also called nonnative or exotic species, are those that humans move, intentionally or accidentally, from native locations to new geographic regions.
 - The modern ease of travel by ship and airplane has accelerated the transplant of species.
- Free from the predators, parasites, and pathogens that limit their populations in their native habitats, transplanted species may spread rapidly through a new region.
- Introduced species may disrupt their adopted community, often by preying on native organisms or outcompeting native species for resources.
 - For example, the brown tree snake was accidentally introduced to the island of Guam after World War II.
 - Since then, 12 species of birds and 6 species of lizards have become extinct due to predation by the brown tree snake.
 - The devastating zebra mussel was accidentally introduced into the Great Lakes of North America in 1988, most likely in the ballast water of ships arriving from Europe.
 - Zebra mussels are efficient suspension feeders that form dense colonies, and they have extensively disrupted freshwater ecosystems, threatening native aquatic species.
 - Zebra mussels have clogged water-intake structures, disrupting domestic and industrial water supplies and causing billions of dollars in damage.
- Humans have introduced many species deliberately, often with disastrous results.

- Mining activities may last for several decades, but the lands are then abandoned in a degraded state.
- Ecosystems may inadvertently be damaged by the dumping of toxic chemicals or by oil spills.
- Restoration ecology seeks to initiate or speed up the recovery of degraded ecosystems.
 - The basic assumption is that environmental damage is at least partially reversible.
 - Communities are not infinitely resilient, however.
 - Restoration ecologists work to identify and manipulate the processes that most limit the speed of recovery, in order to reduce the time it takes for a community to bounce back from disturbance.
- In extreme cases, the structure of a site may need to be restored before biological restoration can occur.
 - Restoration ecologists may reconstruct a meandering stream to slow the flow of water eroding a stream bank.
 - To restore an open-pit mine, engineers may first grade the site to reestablish a gentle slope, spreading topsoil when the slope is in place.
- Two key biological strategies in restoration ecology are bioremediation and augmentation of ecosystem processes.
- **Bioremediation** is the use of living organisms, usually prokaryotes, fungi, or plants, to detoxify polluted ecosystems.
- Restoration ecologists use various types of organisms to remove many different types of toxins from ecosystems.
 - For example, some plants adapted to soils containing heavy metals are capable of accumulating high concentrations of potentially toxic metals.
 - Restoration ecologists can use these plants to revegetate sites polluted by mining and then harvest the plants to remove the metals from the ecosystem.
- Ecologists are exploring the ability of prokaryotes to carry out bioremediation of soils and water.
 - Scientists have sequenced the genomes of at least seven prokaryotic species specifically for their bioremediation potential.
 - One species, *Shewanella oneidensis*, metabolizes more than ten diverse elements in aerobic and anaerobic conditions to generate its energy.
 - For instance, *S. oneidensis* converts soluble uranium, chromium, and nitrogen to insoluble forms that can prevent these pollutants from leaching into streams or groundwater.
 - Wei-Min Wu and colleagues, working at Oak Ridge National Laboratory, Tennessee, added ethanol to groundwater contaminated with uranium to stimulate the growth of *Shewanella* and other uranium-reducing microbes. Over the year and a half of the experiment, uranium concentrations in the groundwater dropped by 80%.
- Genetic engineering may become an increasingly important tool for improving the performance of certain species as bioremediators.
- In contrast to bioremediation, which is a strategy for removing harmful substances, **biological augmentation** uses organisms to add essential materials to a degraded ecosystem.
- Augmenting ecosystem processes requires determining what factors, such as chemical nutrients, have been removed from an area and are limiting its rate of recovery.

- Encouraging the growth of plants that thrive in nutrient-poor soils often speeds up the rate of successional changes that can lead to the recovery of damaged sites.
 - In alpine ecosystems of the western United States, nitrogen-fixing herbs such as lupines are planted to bolster nitrogen concentrations in soils disturbed by mining.
 - When these nitrogen-fixing plants become established, other native species can obtain enough nitrogen from the soil to survive.
- In systems where the soil has been severely disturbed or where topsoil is missing entirely, plant roots may lack the mycorrhizal symbionts that help them meet their nutritional needs.
 - Ecologists restoring a tallgrass prairie in Minnesota significantly accelerated the recovery of native species by adding mycorrhizal symbionts to the soil they seeded.
- Because restoration ecology is a new discipline, there is still much to learn.
- Many restoration ecologists advocate adaptive management—experimenting with several types of management to learn what works best.
- The long-term goal of restoration is to speed the reestablishment of an ecosystem as close as possible to the predisturbance ecosystem.

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