Overview: The Biodiversity Crisis

- **Conservation biology** integrates ecology, evolutionary biology, physiology, molecular biology, genetics, and behavioral ecology to conserve biological diversity at all levels.
- **Restoration ecology** applies ecological principles in an effort to return degraded ecosystems to conditions as similar as possible to their natural, predegraded state.
- 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.
  - 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 we use more than half of the accessible surface fresh water.
  - In the oceans, we have depleted fish stocks by overfishing.
  - Some of the most productive aquatic areas, such as coral reefs and estuaries, are severely stressed.
- Globally, the rate of species loss may be as much as 1,000 times higher than at any time in the past 100,000 years.

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.
  - Humans are threatening Earth’s biodiversity.

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

- Biodiversity has three main components: genetic diversity, species diversity, and ecosystem diversity.
• Genetic diversity comprises the individual genetic variation within a population but also the genetic variation among 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 genetic diversity.
    - 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.

• Species diversity, or species richness, 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 in danger of extinction throughout its range, and a threatened species as one likely to become endangered in the foreseeable future.

• Here are a few examples of why conservation biologists are concerned about species loss.
  - The International Union for Conservation of Natural Resources (IUCN) reports that 12% of the 9,946 known bird species and 24% of the 4,763 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.
  - Harvard biologist Edward O. Wilson has compiled the Hundred Heartbeats Club, a list of species that number fewer than one hundred and are only that many heartbeats away from extinction.
  - Several researchers estimate that at the current rate of destruction, more than half of all plant and animal species will be gone by the end of this new century.

• 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.
  ° We do not know enough about many species to assess their situation.
• The variety of the biosphere's ecosystems is the third level of biological diversity.
  ° The local extinction of one species, especially a keystone predator, can affect an entire community.
  ° Each ecosystem has characteristic patterns of energy flow and chemical cycling that can affect the whole biosphere.
  ° For example, the productive “pastures” of phytoplankton in the oceans may help moderate the greenhouse effect by consuming massive quantities of CO₂ for photosynthesis and for building bicarbonate shells.
  ° Some ecosystems are being erased from the Earth at an astonishing pace.
    ▪ For example, within the contiguous United States, wetland and riparian ecosystems have been altered drastically in the past few centuries.
      * More than 50% of wetlands have been drained and converted to other ecosystems, primarily agricultural.

**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.
• 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.
• 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.
• A few of 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 many agricultural pests by natural enemies.
  ° Protection of shorelines from erosion.
  ° Protection from ultraviolet rays.
  ° Moderation of weather extremes.
  ° Provision of beauty and recreational opportunities.
• The functioning of ecosystems and, hence, their capacity to perform particular services is linked to biodiversity.

*The four major threats to biodiversity are habitat destruction, introduced species, overexploitation, and disruption of interaction networks.*

• Human alteration of habitat is the single greatest threat to biodiversity throughout the biosphere.
  ° 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.

Habitat loss is also 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 humans.
- 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.

Habitat destruction has caused fragmentation of many natural landscapes.

- **Introduced species**, also called invasive species, are those that humans move 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, such transplanted species may spread through a new region at exponential rates.
  - Introduced species usually 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 WWII.
    - Since then, 12 species of birds and 6 species of lizards have become extinct due to predation by the brown tree snake.
  - Humans have introduced many species deliberately, often with disastrous results.
    - The European starling was introduced intentionally to New York’s Central Park by a citizen’s group intent on introducing all the plants and animals mentioned in Shakespeare’s plays.
      - Starling populations in North America now exceed 100 million.
      - They have displaced many native songbirds.

- **Overexploitation** refers to the human harvesting of wild plants and animals at rates that exceed the ability of those populations to rebound.
  - It is possible for overexploitation to endanger certain plant species, such as rare trees that are harvested for their wood.
• However, the term usually applies to commercially hunted or fished animal species.
• Large organisms with low intrinsic reproductive rates are especially susceptible to overexploitation.
  ° The African elephant has been overhunted largely due to the ivory trade.
  ▪ Elephant populations have declined dramatically over the past 50 years.
  ▪ Despite a ban on the sale of new ivory, poaching continues in central and east Africa.
  ° The great auk was overhunted for its feathers, eggs, and meat.
  ▪ It became extinct in the 1840s.
  ° The bluefin tuna is another example of an overharvested species.
  ▪ This big tuna brings $100 per pound in Japan, where it is used for sushi and sashimi.
  ▪ With this demand, it took just ten years to reduce North American bluefin populations to 20% of their 1980 levels.
  ° The collapse of the northern cod fishery off Newfoundland in the 1990s shows that it is possible to overharvest what had been a very common species.

• Ecosystem dynamics depend on networks of interspecific interactions within biological communities.
  ° The extinction of one species can doom others, especially if the extinction involves a keystone species, an ecosystem engineer, or a species with a highly specialized relationship with other species.
  ° Sea otters are a keystone species whose elimination over most of their historic range led to major changes in the structure of shallow-water benthic communities along the west coast of North America.
  ° The extermination of beavers, one of the best-known ecosystem engineers, resulted in a large reduction in wetland and pond habitats across much of North America.

**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 and the declining-population approach.
• The **small-population approach** studies the processes that can cause very small populations to become extinct.
• The **extinction vortex** is a downward spiral unique to small populations.
A small population is prone to positive-feedback loops of inbreeding and genetic drift that draw it into a vortex toward smaller and smaller numbers until extinction is inevitable.

The key factor driving the vortex is the loss of genetic diversity necessary to enable evolutionary responses to environmental change, such as new strains of pathogens.

Not all populations are doomed by low genetic diversity.

Overhunting of northern elephant seals in the 1890s reduced the species to only 20 individuals—clearly a bottleneck that reduced genetic variation.

Since that time, northern elephant seal populations have rebounded to 150,000 individuals, although the genetic variation of the species remains low.

A number of plant species have inherently low genetic variation.

Species of cord grass, which thrive in salt marshes, are genetically uniform at many loci.

Having spread by cloning, this species dominates large areas of tidal mudflats in Europe and Asia.

How small is too small for a population? How small does a population have to be before it starts down the extinction vortex?

The answer depends on the type of organism and its environment, and must be determined case by case.

The greater prairie chicken (Tympanuchus cupido) was common in large areas of North America a century ago.

Agriculture fragmented the population of the greater prairie chicken in the central and western states and provinces.

In Illinois, greater prairie chickens numbered in the millions in the 19th century, declined to 25,000 birds by 1933, and were down to 50 by 1993 (although large populations remained in other states).

The Illinois population of greater prairie chickens has since rebounded, but it was on its way down into an extinction vortex until rescued by a transfusion of genetic variation.

The minimal population size at which a species is able to sustain its numbers and survive is the minimum viable population size (MVP).

Population viability analysis (PVA) is a method of predicting whether or not a species will survive over time.

Modeling approaches such as PVA allow conservation biologists to explore the potential consequences of alternative management plans.

A combination of theoretical modeling and field studies of the managed populations are most effective.
The effective population size ($N_e$) is based on the breeding potential of a population, incorporating information about the sex ratio of breeding individuals.

- $N_e = 4N_f N_m/(N_f + N_m)$
  - $N_f$ and $N_m$ are the numbers of females and males that successfully breed.

- The goal of sustaining $N_e$ stems from concern that populations retain enough genetic diversity.
- Numerous life history traits can influence $N_e$.
  - Formulas for estimating $N_e$ take into account family size, maturation age, genetic relatedness among population members, the effects of gene flow between geographically separated populations, and population fluctuations.
  - In actual populations, $N_e$ is always some fraction of the total population.

One of the first population viability analyses was conducted in 1978 by Mark Shaffer of Duke University as part of a long-term study of grizzly bears in Yellowstone National Park and surrounding areas.

- Grizzly bear ($Ursus arctos horribilis$) populations had been drastically reduced and fragmented.
  - In 1800, an estimated 100,000 grizzlies ranged over more than 500 million hectares of contiguous habitat, while today 1,000 individuals live in six isolated populations with a total range of less than 5 million hectares.
  - Shaffer attempted to determine viable sizes for U.S. grizzly populations.
  - Using life history data obtained for individual bears over a 12-year period, he simulated the effects of environmental factors on survival and reproduction.
    - His models predicted that, given a suitable habitat, a total grizzly bear population of 70 to 90 individuals would have a 95% chance of surviving for 100 years.
  - How does the actual size of the Yellowstone grizzly population compare with Shaffer's estimates of minimum viable population size?
    - Several sources of information indicate that the grizzly population of Yellowstone is growing.
  - The relationship of estimates of total grizzly population to effective population size, $N_e$, is dependent on several factors.
    - Usually, only a few dominant males breed. It may be difficult for them to locate females, since individuals inhabit such large areas.
    - As a result, $N_e$ is about 25% of total population size.
Because small populations tend to lose genetic variation over time, a number of research teams have used protein, mitochondrial DNA, and nuclear microsatellite DNA to assess the genetic variability in the Yellowstone grizzly population.

- These analyses show that the Yellowstone population has lower levels of genetic variability than other grizzly bear populations in North America.
- However, the isolation and decline in genetic variability in the population appears to have been gradual and not as severe as feared.
- The studies also show that the effective size of the Yellowstone grizzly population is larger than formerly thought—approximately 100 individuals.

How might conservation biologists increase the effective size and genetic variation of the Yellowstone grizzly bear population?

- Migration between isolated populations of grizzlies could increase both effective and total population sizes.
- Computer modeling predicts that introducing only two unrelated bears into a population of unrelated bears would reduce the loss of genetic variation in the population by about half.
  - For small populations, finding ways to promote dispersal among populations may be one of the most urgent conservation needs.

The declining-population approach is a proactive conservation strategy for detecting, diagnosing, and halting population declines.

- The small-population approach emphasizes MVP size, and interventions include introducing genetic variation from one population into another.
- The declining-population approach is more action oriented, focusing on threatened and endangered species even when the populations are larger than the MVP.
  - This approach emphasizes the environmental factors that caused a population to decline and requires that population declines be evaluated on a case-by-case basis.
- The declining-population approach takes a number of steps in the diagnosis and treatment of declining populations.
  1. Assess population trends and distribution to confirm that the species is in decline or that it was formerly more abundant.
  2. Study the species' natural history to determine its environmental requirements.
3. Develop hypotheses for all the possible causes of the decline, including human activities and natural events, and list the predictions for further decline of each hypothesis.

4. Test the most likely hypothesis first to determine if this factor is the main cause of the decline. For example, remove the suspected agent of decline to see if the experimental population rebounds relative to a control population.

5. Apply the results of this diagnosis to the management of the threatened species and monitor recovery.

- The red-cockaded woodpecker (*Picoides borealis*) is an endangered species endemic to the southeastern United States.
  - To take the declining-population approach, we must understand the habitat requirements of an endangered species.
  - This species requires mature pine forest, preferably dominated by longleaf pine, for its habitat.
  - The red-cockaded woodpecker drills its nest holes in mature, living pine trees.
    - Red-cockaded woodpeckers drill small holes around the entrance to their nest cavities, which causes resin from the tree to ooze down the trunk.
    - The resin repels certain predators that eat bird eggs and nestlings.
  - The understory of plants around the pine trunks must be low profile so the woodpeckers have a clear flight path into their nests.
    - Historically, periodic fires swept through longleaf pine forests, keeping the understory low.
  - One factor leading to the decline of the red-cockaded woodpecker is the destruction or fragmentation of suitable habitat by logging and agriculture.
  - Recognition of the key habitat factors, protection of some longleaf pine forests, and the use of controlled fires to reduce forest undergrowth have helped restore habitat that can support viable populations.
    - However, designing a recovery program was complicated by the birds' social organization.
    - Red-cockaded woodpeckers live in groups of one breeding pair and up to four male helpers.
      - Helpers are offspring who do not disperse and breed but remain behind and assist in incubating eggs and feeding nestlings.
      - They may wait years before attaining breeding status.
      - Young birds that disperse usually occupy abandoned territories or excavate nesting cavities, which can take several years.
Individuals have a better chance of reproducing by remaining as helpers than by dispersing and excavating homes in new territories.

Ecologists tested the hypothesis that social behavior restricts the ability of the red-cockaded woodpecker to rebound.

- They constructed new cavities in pine trees and found that 18 of the 20 sites were colonized by red-cockaded woodpeckers.
- This experiment supported the hypothesis that red-cockaded woodpeckers had been leaving suitable habitats unoccupied because of an absence of breeding cavities.

This is a good example of how understanding habitat can lead to a successful conservation effort.

**Conserving species involves weighing conflicting demands.**

- Conservation biology often highlights the relationship between science, technology, and society.
  - For example, programs to restock wolves in Yellowstone Park are opposed by many ranchers concerned with potential loss of livestock.

- Large, high-profile vertebrates are not always the focal point in such conflicts, but habitat use is almost always an issue.
  - Should a highway bridge be built if it destroys the only remaining habitat of a species of freshwater mussel?

- Another important consideration is the ecological roles of species.
  - We cannot save every endangered species, so we must determine which are most important for conserving biodiversity as a whole.
  - Species do not exert equal influence on community and ecosystem processes.
  - Identifying keystone species and finding ways to sustain their populations can be central to the survival of whole communities.

- Management aimed at conserving a single species carries with it the possibility of negatively affecting populations of other species.
  - For example, management of pine forests for the red-cockaded woodpecker might impact migratory birds associated with broadleaf temperate forests.
  - To test for such impacts, ecologists compared bird communities near clusters of nest cavities in managed pine forests with communities in forests not managed for woodpeckers.
The managed sites actually supported higher numbers and diversity of other birds than the control forests.

**Concept 56.3 Landscape and regional conservation aim to sustain entire biotas**
- On a broad scale, the principles of community, ecosystem, and landscape ecology can be brought to bear on studies of the biodiversity of entire landscapes.
  - Human population dynamics and economics are also considered.
- **Landscape ecology** is the application of ecological principles to the study of human land-use patterns.
  - A landscape is a regional assemblage of interacting ecosystems.
  - This type of ecology is important in conservation biology because many species use more than one type of ecosystem and many live on the borders between ecosystems.

*Edges and corridors can strongly influence landscape biodiversity.*
- Boundaries, or edges, between ecosystems and within ecosystems are defining features of landscapes.
  - An edge has its own set of physical conditions, which differ from those on either side of it.
  - Edges have their own communities of organisms.
- Some organisms thrive in edge communities because they have access to the resources of both adjacent areas.
  - For example, the ruffed grouse (*Bonasa umbellatus*) requires forest habitat for nesting, winter food, and shelter.
  - It also needs forest openings with dense shrubs and herbs for summer food.
- The proliferation of edge species can have positive or negative effects on a community’s biodiversity.
  - For example, a 1997 study in Cameroon suggested that forest edges may be important sites of speciation.
  - On the other hand, communities in which edges have resulted from human alterations often have reduced biodiversity because of domination by edge-adapted species.
  - **Cowbirds** flourish in areas where forests are heavily cut and fragmented, creating more edge habitat and open land.
  - Increasing cowbird parasitism and loss of habitat are correlated with declining populations of cowbird’s host species.
• The influence of fragmentation on the structure of communities has been explored for two decades in the long-term Biological Dynamics of Forest Fragments Project in the Amazon River basin.
  ◦ Researchers are clearly documenting the physical and biological effects of forest fragmentation in taxa ranging from bryophytes to beetles to birds.
  ◦ Species adapted to forest interiors show the greatest declines in the smallest fragments, suggesting that landscapes dominated by small fragments will support fewer species, mainly due to loss of interior-adapted species.

• A movement corridor is a narrow strip or series of small clumps of good habitat connecting otherwise isolated patches.
  ◦ Such corridors can be deciding factors in conserving biodiversity.
  ◦ Streamside habitats often serve as corridors. Some nations prohibit destruction of these riparian areas.

• In areas of heavy human use, artificial corridors have been constructed.
  ◦ For example, a bridge in Banff National Park helps animals cross a major highway.

• Movement corridors can promote dispersal and reduce inbreeding in declining populations.
  ◦ They are especially important to species that migrate between different habitats seasonally.

• However, corridors can also be harmful, aiding in the spread of disease.
  ◦ Habitat corridors facilitated the movement of disease-carrying ticks among forest patches in northern Spain.

Conservation biologists face many challenges in setting up protected areas.

• Conservation biologists apply ecological research in setting up reserves or protected areas to slow the loss of biodiversity.
  ◦ Governments have set aside about 7% of the world’s land in various types of reserves.

• Choosing locations for protection and designing nature reserves pose many challenges.
  ◦ If a community is subject to fire, grazing, and predation, should the reserve be managed to reduce these processes? Or should the reserve be left as natural as possible?

• Much of the focus has been on biodiversity hot spots, areas with exceptional concentrations of endemic species and a large number of threatened or endangered species.
  ◦ Nearly 30% of all bird species are confined to only 2% of the Earth’s land area.
About 50,000 plant species (17% of those known) inhabit 178 hot spots that comprise only 0.5% of the global land species.

Hot spots also include aquatic ecosystems, such as coral reefs and certain river systems.

Biodiversity hot spots are obvious choices for reserves, but recognizing them can be difficult.

- A hot spot for one taxonomic group may not be a hot spot for another taxonomic group.
- Designating an area as a biodiversity hot spot is often biased toward vertebrates and plants, with less attention paid to invertebrates and microorganisms.

Nature reserves must be functional parts of landscapes.

- It is important that nature reserves are not isolated from the natural environment.
- Disturbance is a functional component of all ecosystems, and management policies that ignore natural disturbances or attempt to prevent them are generally self-defeating.
  - For instance, setting aside an area of a fire-dependent community, such as tallgrass prairie or dry pine forest, without periodic burning is unrealistic.
  - Without the dominant disturbance, fire-adapted species are usually outcompeted by other species, and biodiversity is reduced.

- A major conservation question is whether it is better to create one large reserve or a group of smaller ones.
  - Extensive reserves are beneficial for large, far-ranging animals with low-density populations, such as the grizzly bear.
  - As conservation biologists learn more about the requirements for achieving minimum viable population sizes for endangered species, it is clear that most national parks and other reserves are far too small.
    - The biotic boundary, the area needed to sustain the grizzly, is more than ten times as large as the legal boundary, the actual area of the parks.
  - In some cases, when reserve land is surrounded by commercially viable property, the use of land for agriculture or forestry must be integrated into conservation strategies.

- Several nations have adopted an approach to landscape management called zoned reserve systems.
  - A zoned reserve is a large region of land that includes one or more areas undisturbed by humans surrounded by lands that are used for economic gain and have been changed by humans.
• The key challenge of the zoned reserve approach is to develop a social and economic climate in the surrounding lands that is compatible with the long-term viability of the protected core area.
  ° The surrounding areas continue to be used to support the human population, but with regulations to prevent the types of extensive alterations that will impact the protected area.
  ° The surrounding tracts of land serve as buffer zones against intrusion into the undisturbed areas.
• The small Central American nation of Costa Rica has become a world leader in establishing zoned reserves.
  ° Costa Rica has eight zoned reserves, called "conservation areas," which contain national park land.
  ° The buffer zones provide a steady, lasting supply of forest products, water, and hydroelectric power, as well as support sustainable agriculture and tourism.
• Costa Rica hopes to maintain at least 80% of its native species in its zoned reserves.
  ° A 2003 analysis of land cover change between 1960 and 1997 showed negligible deforestation in Costa Rica's national parks and a gain in forest cover in the 1-km buffer around the parks.
  ° However, significant losses in forest cover were discovered in the 10-km buffer zone around all national parks, which threatens to turn the parks into isolated habitat islands.
• The continued high rate of human exploitation of ecosystems leads to the prediction that less than 10% of the biosphere will ever be protected as nature reserves.
  ° Sustaining biodiversity often means working in landscapes that are almost entirely human dominated.
  ° For example, commercially important fish populations around the world have collapsed in the face of mounting fishing pressure from increasingly sophisticated fishing equipment.
    ▪ It has been proposed that marine reserves be established around the world that are off limits for fishing.
    ▪ Such reserves would increase fish populations within the reserves and improve fishing success in nearby areas.

**Concept 56.4 Restoration ecology attempts to restore degraded ecosystems to a more natural state**

• Restoration ecology applies ecological principles in developing ways to return degraded areas to natural conditions.
  ° Biological communities can recover from many types of disturbances through a series of restoration mechanisms that occur during ecological succession.
• The amount of time required for such natural recovery is more closely related to the spatial scale of the disturbance than the type of disturbance.
  ° The larger the area disturbed, the longer the time required for recovery.

• However, communities are not infinitely resilient.
• 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.
  ° Natural disturbances such as periodic fires or floods are part of the dynamics of many ecosystems and need to be considered in restoration strategies.

• **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.
  ° The bacterium *Pseudomonas* has been used to clean up oil spills on beaches.
  ° Genetic engineering may become increasingly important as a 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 recovery of damaged sites.
    ▪ An example is the rapid regrowth of indigenous plants alongside roads in Puerto Rico after colonization of the areas by a nonnative plant that thrives on nitrogen-poor soils.
      * The rapid buildup of organic material from the nonnative plant enabled the indigenous plants to recolonize the area and overgrow the introduced species.

• 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 key to adaptive management (and the key to restoration ecology) is to consider alternative ways of accomplishing goals and to learn from mistakes as well as successes.

- The long-term goal of restoration is to speed the reestablishment of an ecosystem as close as possible to the predisturbance ecosystem.

**Concept 56.5 Sustainable development seeks to improve the human condition while conserving biodiversity**

- Many have embraced the concept of sustainable development, the long-term prosperity of human societies and the ecosystems that support them.

- The Sustainable Biosphere Initiative is a research agenda endorsed by the Ecological Society of America.
  - The goal is to obtain the basic ecological information necessary for responsible development, management, and conservation of Earth’s resources.

- The research agenda includes studies of global change, including interactions between climate and ecological processes, biological diversity and its role in maintaining ecological processes, and the ways in which the productivity of natural and artificial ecosystems can be sustained.
  - This initiative requires a strong commitment of human and economic resources.

- Sustainable development is not just about science.
  - It must include life sciences, social sciences, economics, and humanities.
  - Equally important, it requires a reassessment of our values.

- The success of conservation in Costa Rica has involved leadership by the national government as well as an essential partnership with nongovernmental organizations and private citizens.

- How have living conditions of Costa Ricans fared as the country pursued conservation goals?
  - Infant mortality rate in Costa Rica declined sharply during the 20th century, and life expectancy at birth increased.
  - The 2003 literacy rate in Costa Rica was 96%.

- Such statistics show that living conditions in Costa Rica improved greatly over the period in which the country dedicated itself to conservation and restoration.
• One of the challenges the country faces is maintaining its commitment to conservation in the face of a growing population.
  ° Costa Rica’s population, currently 4 million, is predicted to grow to 6 million people over the next 50 years.
  ° It is likely that the Costa Rican people will confront the remaining challenges of sustainable development with success.

**The future of the biosphere may depend on our biophilia.**

• Not many people live in truly wild environments or even visit such places.

• **Biophilia** includes our sense of connection to diverse organisms and our attachment to pristine landscapes.
  ° Most biologists have embraced this idea.

• We should be motivated to preserve biodiversity because we depend on it for many resources.

• Maybe we can also work to prevent the extinction of other forms of life because it is the ethical thing to do.
  ° Biology is a scientific expression of our desire to know nature.
    ▪ We are most likely to protect what we appreciate, and we are most likely to appreciate what we understand.

• By learning about the processes and diversity of life, we become more aware of ourselves and our place in the biosphere.