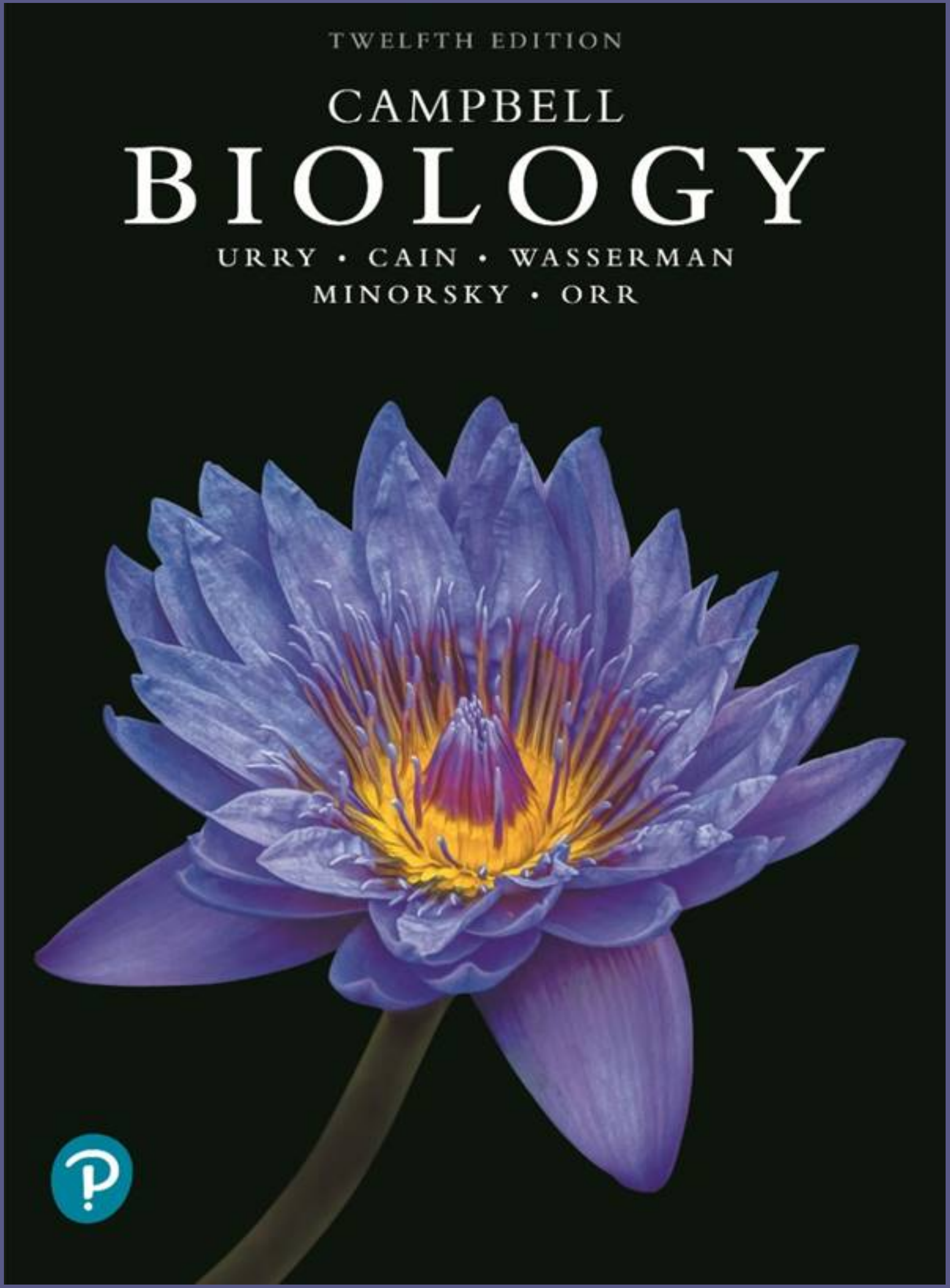


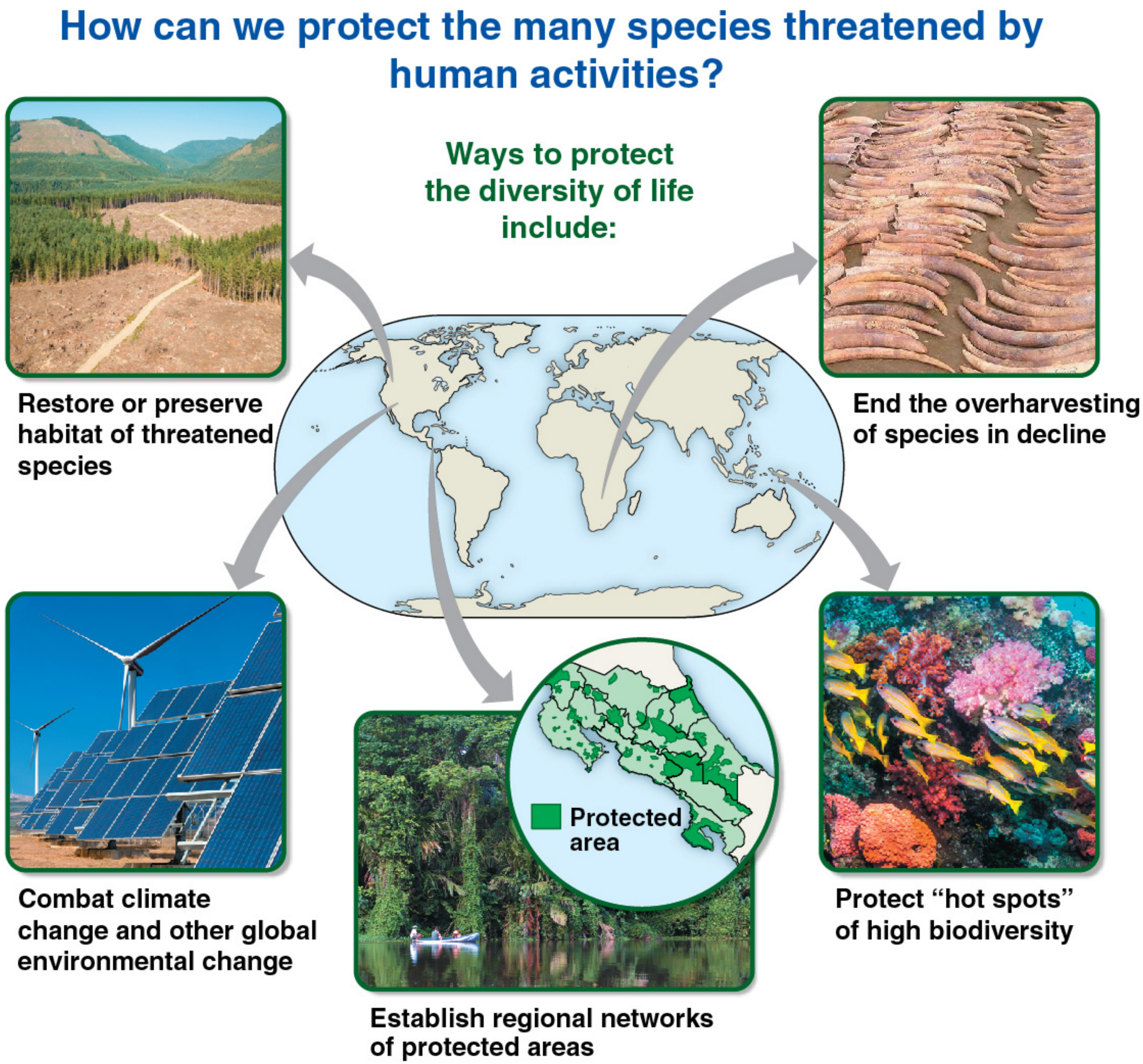
Chapter 56

Conservation Biology and Global Change

Lecture Presentations by
Nicole Tunbridge and
Kathleen Fitzpatrick

Figure 56.1a

Figure 56.1b


How can we protect the many species threatened by human activities?
Ways to protect the diversity of life include:
Restore or preserve habitat of threatened species
End the overharvesting of species in decline
Combat climate change and other global environmental change
Protected area
Establish regional networks of protected areas
Protect “hot spots” of high biodiversity

CONCEPT 56.1: Human activities threaten Earth's biodiversity

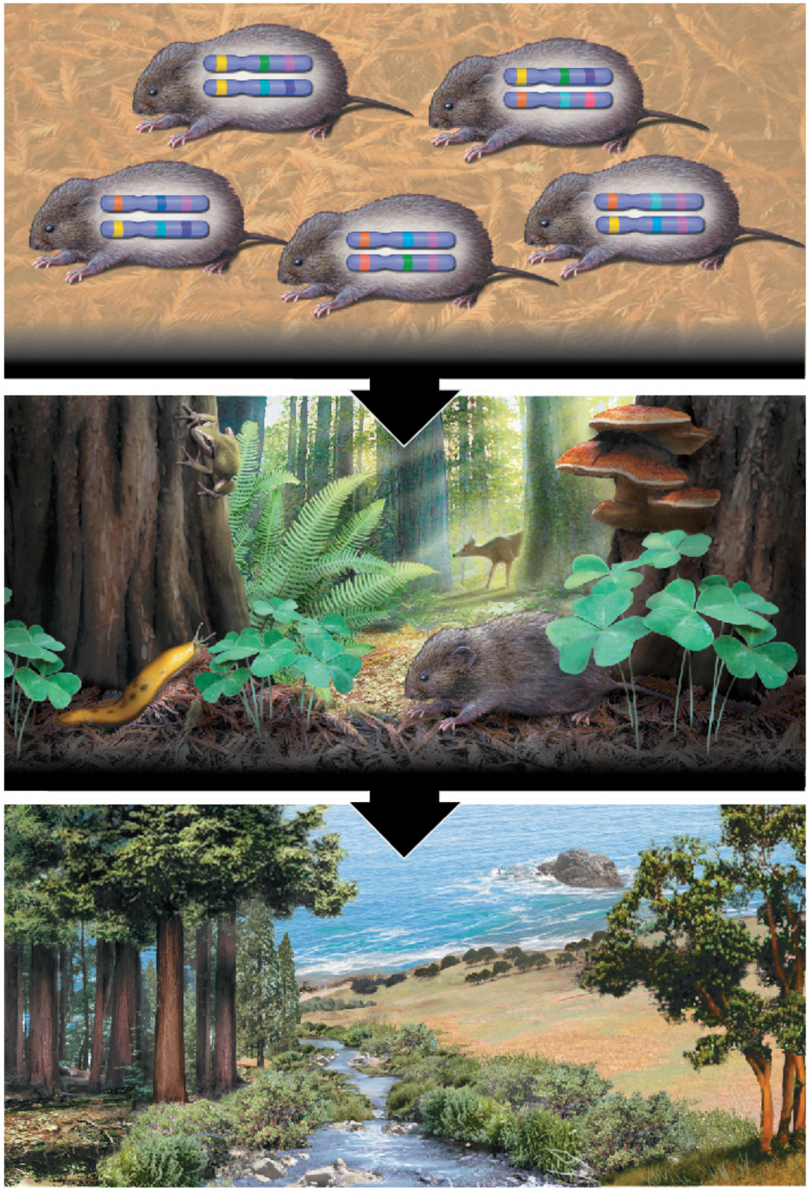
- Human activities alter natural disturbance, trophic structure, energy flow, and chemical cycling
- **Conservation biology** integrates ecology, physiology, molecular biology, evolutionary biology, and genetics in effort to conserve biological diversity

- Extinction is a natural phenomenon, but the current high rate of extinction is of concern
- The current rate of extinction is 100 to 1,000 times the “background,” or typical extinction rate
- Human activities threaten biodiversity at all levels

Three Levels of Biodiversity

- Biodiversity can be considered at three main levels:
  - Genetic diversity
  - Species diversity
  - Ecosystem diversity

Figure 56.2



Genetic diversity in a vole population

Species diversity in a coastal redwood ecosystem

Community and ecosystem diversity across the landscape of an entire region

Genetic Diversity

- Genetic diversity comprises genetic variation within a population and between populations
- The extinction of a population reduces the genetic diversity required for microevolution within a species

Species Diversity

- Species diversity is the number of species in an ecosystem or across the biosphere
- There are 1.8 million named species of organisms
- The actual number of species on Earth is estimated to be from 5 million to 100 million

- Endangered and threatened species are of particular concern
  - An **endangered species** is one that is in danger of extinction throughout all or much of its range
  - A **threatened species** is considered likely to become endangered in the foreseeable future

Figure 56.3

Philippine eagle

Yangtze River dolphin

- A few statistics illustrate the problem of species loss
  - Globally, 13% of birds are endangered and 22% of mammal species are threatened
  - Of 20,000 known plant species in the United States, 200 are extinct and 730 are endangered or threatened
  - Since 1900, 123 freshwater animal species have become extinct in North America; hundreds more are threatened

- Global extinction means that a species is lost from all ecosystems in which it lived
- Extinctions may also occur at the local population level; lost from one area, but surviving in others

Video: Surveying Gorongosa's Biodiversity

[crickets chirp]

Ecosystem Diversity

- Human activity is reducing ecosystem diversity, the variety of ecosystems in the biosphere
  - For example, more than half of the 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
  - Their extinction would harm native plant communities

Figure 56.4

Biodiversity and Human Welfare

- There are a number of arguments for why humans should care about the loss of biodiversity
  - Biophilia, our human sense of connection to nature
  - Morality, other species are entitled to life
  - Obligation, preservation for future generations
  - Benefits, of species and genetic diversity

Benefits of Species and Genetic Diversity

- Species related to agricultural crops can have important genetic qualities
  - For example, virus-resistant rice was produced by crossing commercial rice with a resistant wild population

- In the United States, 25% of prescriptions contain doriginally derived from plants
  - For example, the rosy periwinkle contains alkaloids that inhibit cancer growth

Figure 56.5

- Genetic diversity in nature can have benefits to humans
  - For example, diverse prokaryote DNA is used to produce medicines, food, petroleum substitutes, industrial chemicals, and other products

Ecosystem Services

- **Ecosystem services** encompass the processes by which natural ecosystems help sustain human life
- Some examples of ecosystem services include
  - Purification of air and water
  - Detoxification and decomposition of wastes
  - Crop pollination, pest control, and soil preservation
  - Moderation of weather extremes and flooding

- The value of Earth’s ecosystem services was estimated at $33 trillion per year in 1997
- Loss of biodiversity reduces ecosystem capacity to perform processes critical to our survival

Threats to Biodiversity

- Most biodiversity loss is traced to four major threats:
  - Habitat loss
  - Introduced species
  - Overharvesting
  - Global change

Habitat Loss

- Human alteration of habitat through agriculture, forestry, urban development, mining, and pollution is the greatest threat to biodiversity
- Habitat loss is implicated as the contributing cause for 73% of species that have become extinct, endangered, vulnerable, or rare in the last few hundred years

- Habitat loss and fragmentation occur over immense regions
  - For example, about 98% of the tropical dry forests of Central America and Mexico have been cut down
  - More than 90% of the original tropical rain forest in the state of Veracruz, Mexico, has been cleared

Figure 56.6

- Small populations in small habitat fragments are vulnerable to extinction
  - For example, European settlement reduced prairie habitat in southern Wisconsin from 800,000 hectares to only 800 hectares today
  - Plant diversity declined by 8–60% from 1948–1988

- Habitat loss is a major threat to aquatic biodiversity
  - For example, about 70% of coral reefs have been damaged by human activities
  - Reefs are home to one-third of marine fish species
  - At the current rate of destruction, 40–50% of reefs could be lost in the next 30 to 40 years

Introduced Species

- **Introduced species** are those that humans move from native locations to new geographic regions, either intentionally or by accident
- Free from native predators, herbivores, pathogens or competitors, introduced species may spread rapidly

- Introduced species that establish may prey upon or outcompete native organisms
  - For example, the arrival of the predatory brown tree snake on the island of Guam was followed by extinctions of several bird and lizard species

- Humans have deliberately introduced some species with good intentions but disastrous effects
  - For example, kudzu, a plant species intentionally introduced to control erosion in the southern United States, has taken over large areas of the landscape

Figure 56.7

- Introduced species have contributed to about 40% of worldwide extinctions recorded since 1750
- They cost billions of dollars each year in damage and control efforts
- There are currently more than 50,000 introduced species in the United States

Overharvesting

- Overharvesting is harvesting of organisms at rates exceeding the ability of their populations to rebound
- Species with restricted habitats, such as islands, are especially vulnerable to overharvesting

- Large organisms with low reproductive rates are susceptible to overharvesting
  - For example, illegal hunting for the ivory trade reduced populations of African elephants by 22% from 2006 to 2015
  - If not protected, elephants could become extinct in the wild across most of Africa

- DNA analysis helps conservation biologists identify the source of illegally obtained animal products
  - For example, using DNA from illegally harvested ivory, researchers can determine to within a few hundred kilometers where the elephants were killed

Figure 56.8

- Overfishing has decimated many commercially important wild fish populations
  - For example, the western Atlantic bluefin tuna population declined by over 80% in the 1980s due to increased harvest for the sushi industry in Japan

Figure 56.9

Global Change

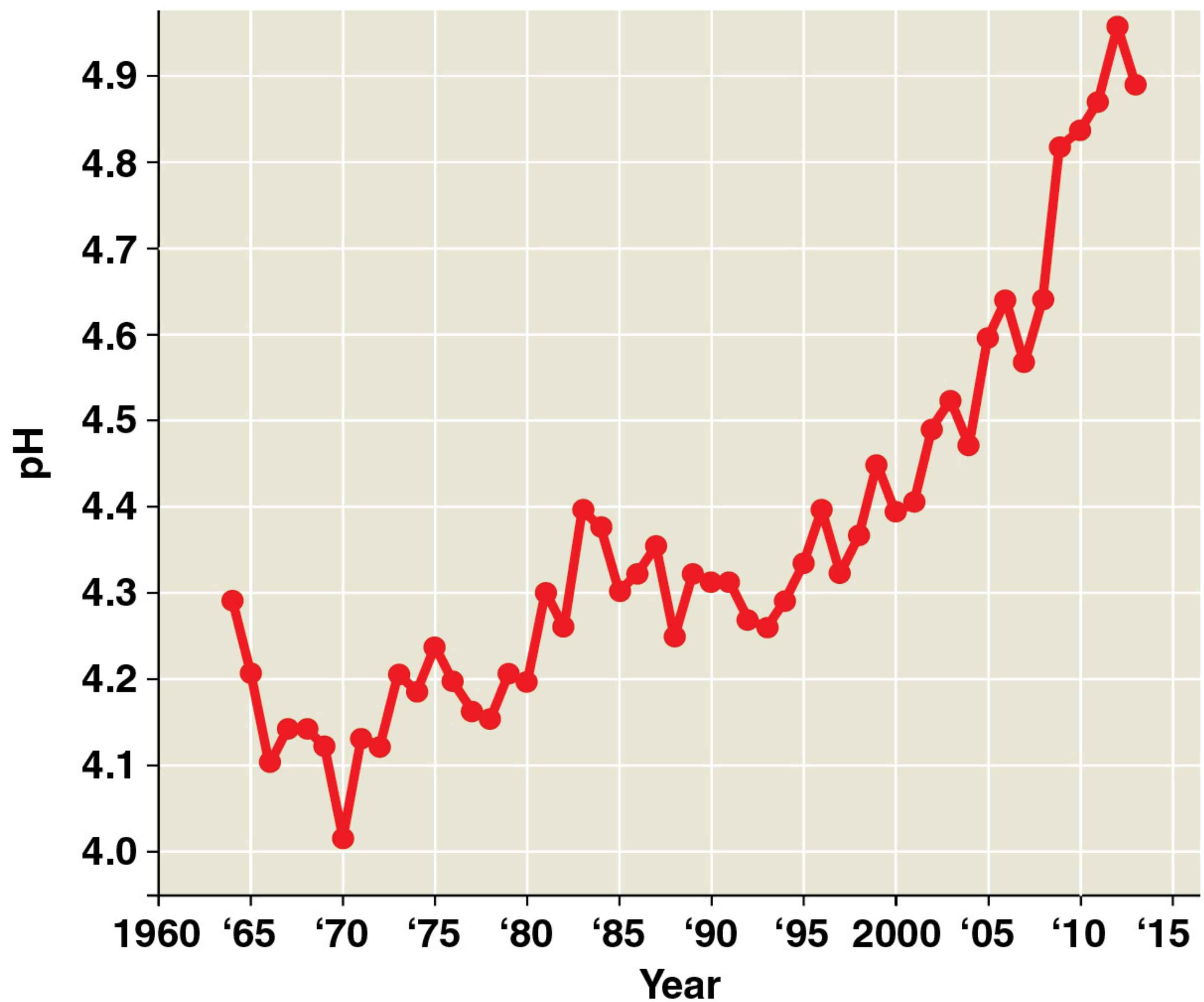
- Global change includes alterations in climate, atmospheric chemistry, and broad ecological systems that reduce Earth’s capacity to support life

- Acid precipitation is rain, snow, or fog that contains sulfuric or nitric acids causing a pH < 5.2
- Acids form in the atmosphere with the release of sulfur and nitrogen from burning wood and fossil fuel
- Chemical reactions with acids decrease nutrient and increase toxic metal concentrations in soil and water, harming some organisms

- Air pollution from one region can result in acid precipitation downwind
  - For example, industrial pollution in the Midwestern United States caused acid rain that killed lake-dwelling organisms in eastern Canada in the 1960s

- Environmental regulations help decrease acid precipitation, but recovery of aquatic ecosystems will take decades
- Sulfur dioxide emissions decreased more than 75% in the United States between 1990 and 2013, but emissions of nitrogen oxides are increasing

Figure 56.10


4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4.0
pH
1960
‘65
‘70
‘75
‘80
‘85
‘90
‘95
2000
‘05
‘10
‘15
Year

Can Extinct Species Be Resurrected?

- Scientists are attempting to use cloning techniques to prevent extinctions and resurrect species that have become extinct
  – For example, researchers created hybrid embryos using sperm from the near extinct northern white rhinoceros and eggs from the southern subpopulation

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

- Biologists working on conservation at the population and species levels use two main approaches:
  - Focus on extinction risk in small populations
  - Focus on critical habitat

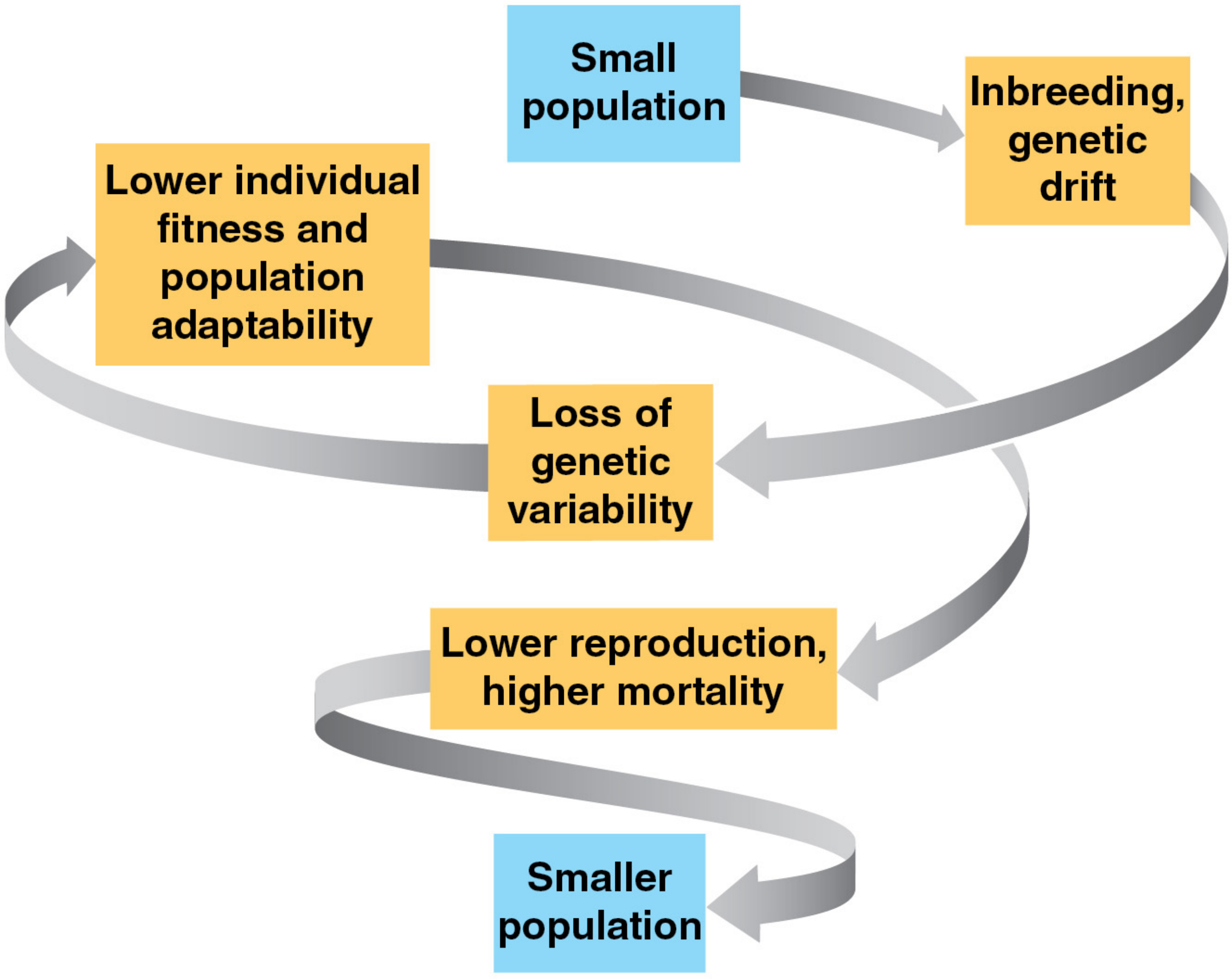
Extinction Risks in Small Populations

- Small populations are vulnerable to habitat loss, overharvesting, and other threats to biodiversity
- Once reduced, the small size itself can push the population to extinction

The Extinction Vortex: Evolutionary Implications of Small Population Size

- Inbreeding and genetic drift can draw a small population down an **extinction vortex** toward smaller size and eventual loss of all individuals
- One key factor is the loss of genetic variation needed to adapt to changes in the environment

Figure 56.11


Small population
Inbreeding, genetic drift
Loss of genetic variability
Lower individual fitness and population adaptability
Lower reproduction, higher mortality
Smaller population

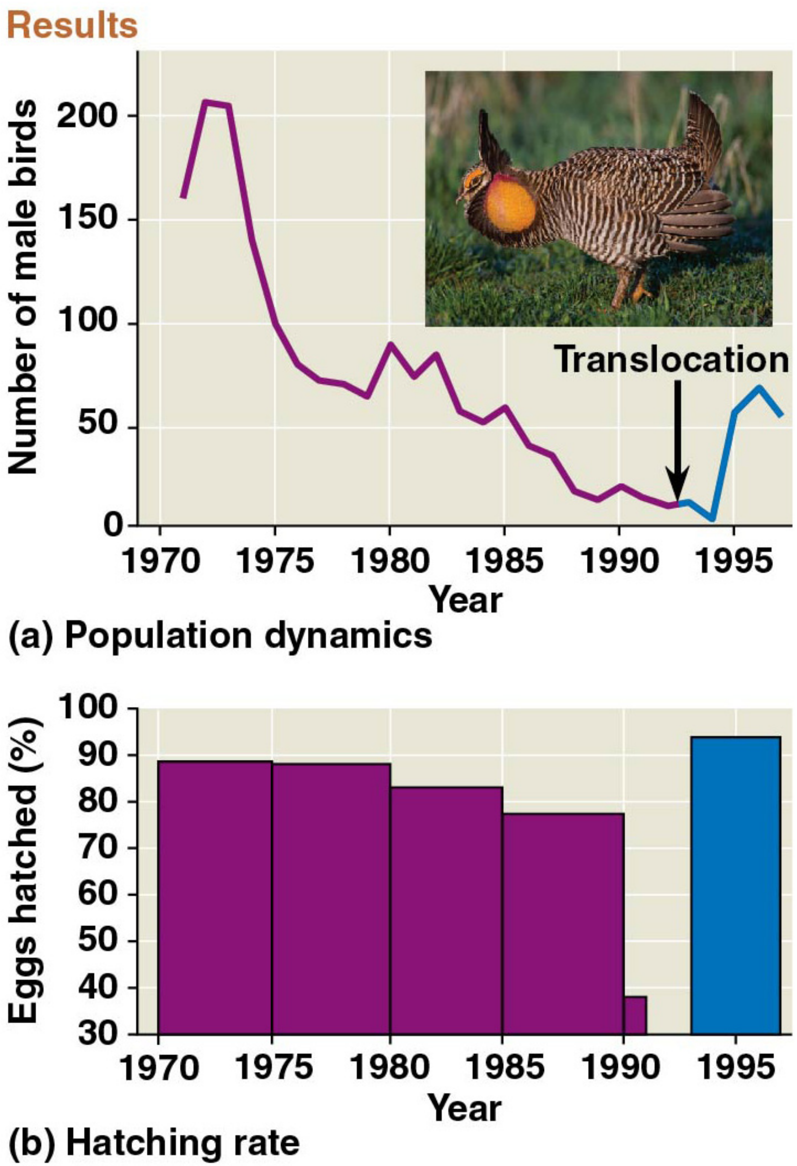
- Not all small populations are doomed by low genetic diversity, and low genetic diversity does not automatically lead to permanently small populations
  - For example, northern elephant seals were reduced to only 20 individuals in the 1890s, but they rebounded to about 150,000 individuals today
  - The genetic variation remains low in the population

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

- Land cultivation for agriculture fragmented the greater prairie chicken populations in North America
- The Illinois population fell to less than 50 by 1993
- The decline was associated with reduced fertility and genetic variation

- Researchers imported birds from outside Illinois to increase the genetic variation of the population
- The Illinois population rebounded, indicating it was on the way to extinction before the transfusion of genetic variation

Figure 56.12


Results
Number of male birds
200
150
100
50
0
Translocation
1970
1975
1980
1985
1990
1995
Year
(a) Population dynamics
Eggs hatched (%)
100
90
80
70
60
50
40
30
1970
1975
1980
1985
1990
1995
Year
(b) Hatching rate

Minimum Viable Population Size

- **Minimum viable population (MVP)** is the minimum population size at which a species can sustain its numbers
- MVP is estimated by integrating many factors, such as an estimate of how many individuals are likely to be killed by storms or other catastrophes

Effective Population Size

- The **effective population size**, based on the population's breeding potential, is a fraction of the actual population size
- An estimate of the effective population size is required to estimate MVP

- 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

- MVP is often used in population viability analysis
- Viability analysis is used to predict a population’s chances for survival over a particular time interval

Case Study: *Analysis of Grizzly Bear Populations*

- Population viability analysis was used in a study of grizzly bears in Yellowstone National Park in 1978
- Life history data was obtained for individual bears over a 12-year period
- The data was used to simulate the effects of environmental factors on survival and reproduction

Figure 56.13

- The models predicted that, given a suitable habitat
  - A population of 70 to 90 bears had a 95% chance of surviving for 100 years
  - A population of 100 bears had a 95% chance of surviving about 200 years
- There are currently about 700 grizzlies in the greater Yellowstone ecosystem; N_e is about 175

- The Yellowstone grizzly population has low genetic variability compared with other grizzly populations
- Introducing two unrelated bears per decade into a population of 100 would reduce the loss of genetic variation by half
- Promoting dispersal among wildlife populations is an urgent conservation need

Critical Habitat

- Loss of critical habitat can cause threatened and endangered populations to decline, even those well above MVP
- Focus on critical habitat emphasizes environmental factors that cause the decline

Case Study: *Decline of the Red-Cockaded Woodpecker*

- Red-cockaded woodpeckers require living trees in mature pine forests for nesting
- Small holes drilled around the entrance to the nest cavity ooze resin that helps repel predators
- Undergrowth must be low to allow a clear flight path between home trees and feeding grounds

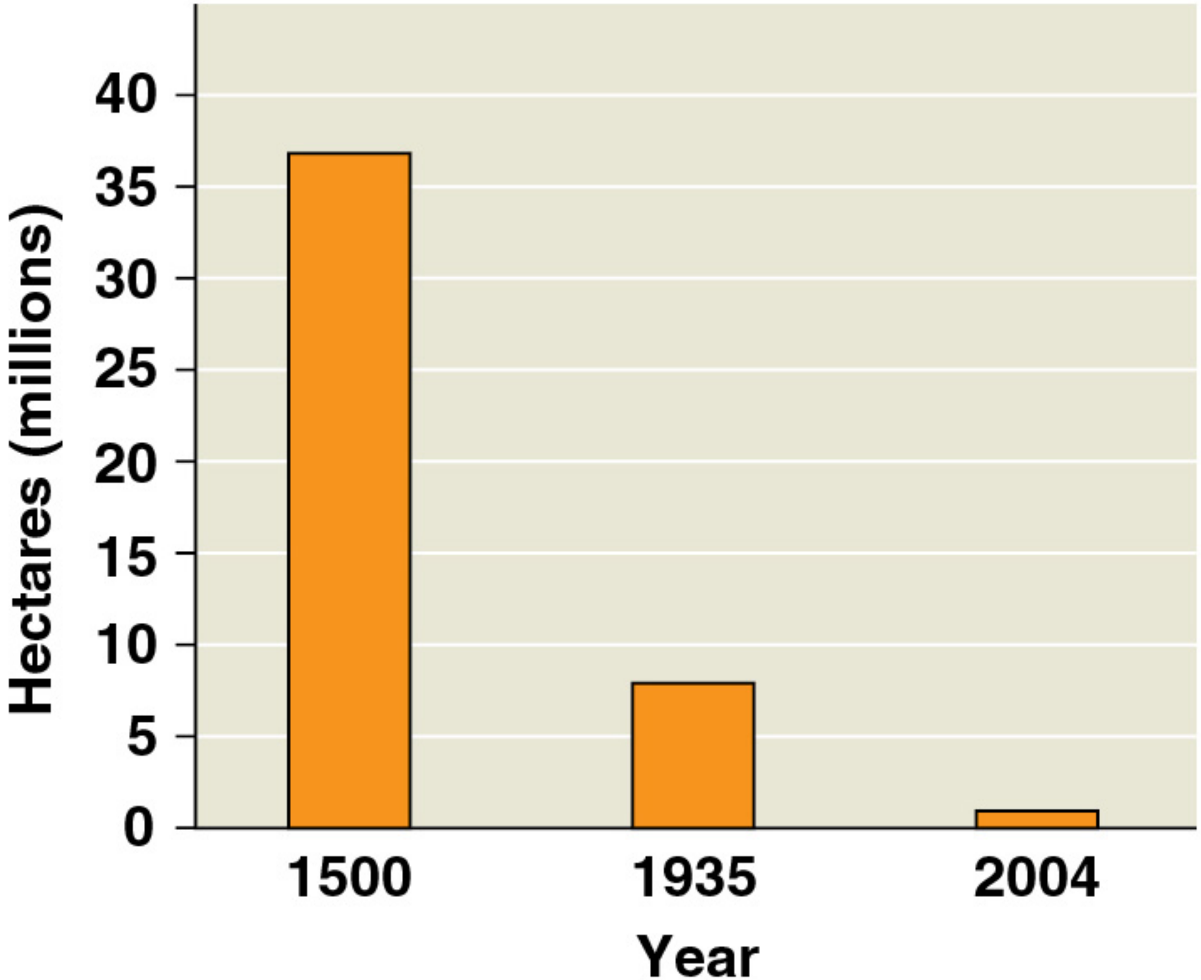
Figure 56.14

(a) Forests with low undergrowth can sustain woodpeckers

(b) Forests with high, dense undergrowth cannot sustain woodpeckers

- Suitable habitat has been destroyed or fragmented by logging and agriculture
- Recognition of key habitat factors allows conservation and restoration of critical habitat
  - For example, controlled fires can be used to reduce forest undergrowth in protected habitat

Figure 56.15



- Red-cockaded woodpeckers take months to excavate new nesting cavities
- Research indicates that new breeding groups form only where breeding cavities are constructed
- Species recovery has begun in response to habitat maintenance including controlled burning and nest cavity excavation

Weighing Conflicting Demands

- Successful conservation efforts resolve conflicts between human demands and the habitat needs of species
  - For example, in the western United States, the habitat needs of wolf, grizzly, and bull trout populations conflict with grazing and resource extraction industries

- Not all species can be saved; each species must be assessed based on its ecological role and importance for conserving biodiversity
- Identifying and sustaining keystone species can be central to maintaining communities and ecosystems

CONCEPT 56.3: Landscape and regional conservation help sustain biodiversity

- Conservation efforts have historically focused on saving individual species
- Today, the emphasis is on sustaining the biodiversity of entire communities, ecosystems, and landscapes

Landscape Structure and Biodiversity

- The physical features, or structure, of a landscape can strongly influence biodiversity
- Many species use more than one kind of ecosystem or live on the borders between ecosystems

Fragmentation and Edges

- The boundaries, or edges, between ecosystems are defining features of landscapes
- An edge has its own set of physical conditions, which differ from those on either side of it
- Some species take advantage of edge communities to access resources from both adjacent areas

Figure 56.16

- Fragmentation of the landscape due to human activity favors species that thrive in edge habitat
  - For example, white-tailed deer thrive in edge habitat and increase in abundance when forests are logged
- Species adapted to forest interiors show the greatest decline in small habitat patches
- Landscapes dominated by small fragments are likely to support fewer species

Figure 56.17

Corridors That Connect Habitat Fragments

- A **movement corridor** is a narrow strip or series of small clumps of habitat connecting otherwise isolated patches
- Movement corridors promote dispersal and reduce inbreeding
- In areas of heavy human use, artificial corridors are sometimes constructed

Figure 56.18

- Corridors can also be harmful by facilitating the spread of disease-carrying organisms between populations

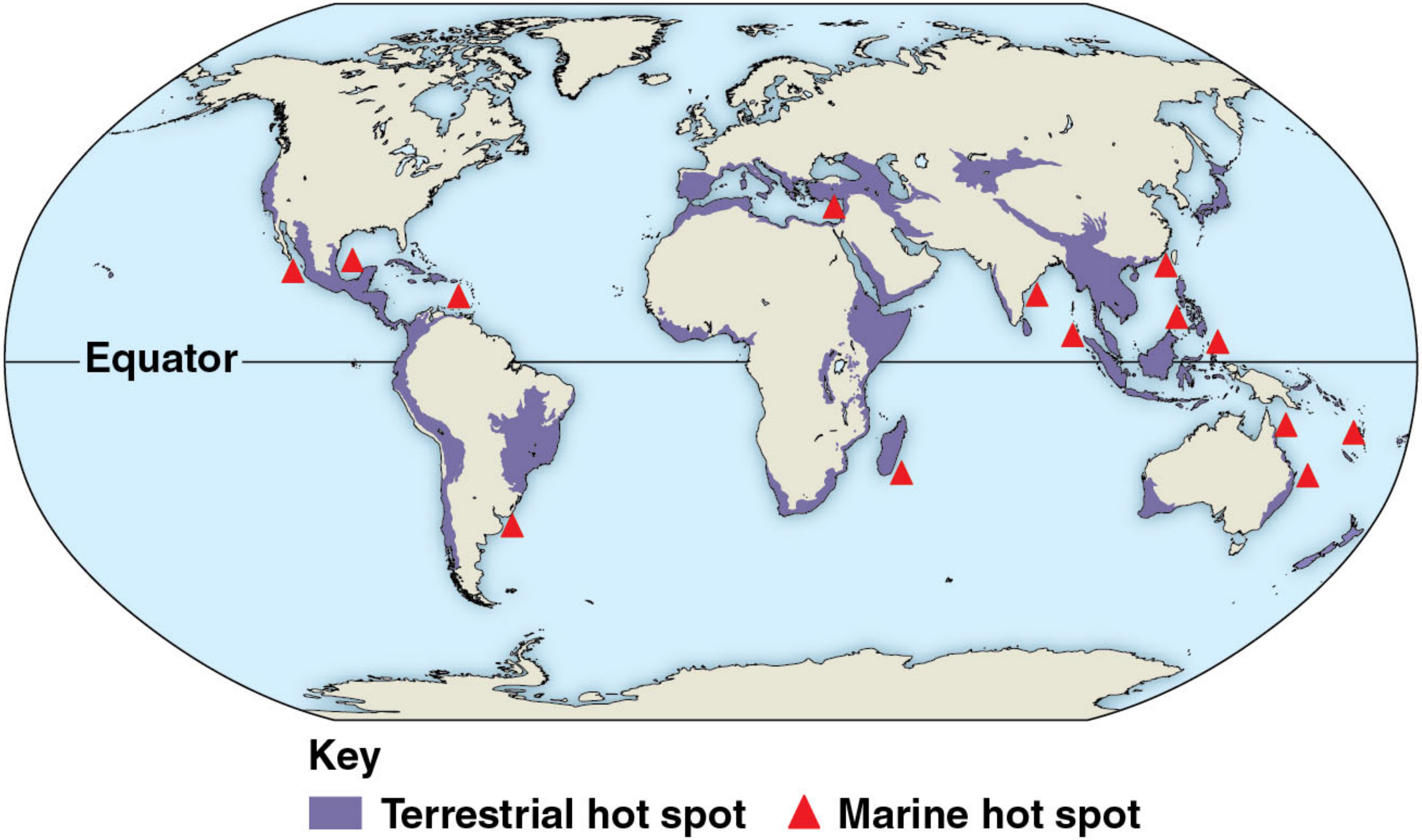
Establishing Protected Areas

- Governments have set aside about 7% of the world's land in various forms of reserves
- Placement and design of reserves pose many challenges
  - For example, should the reserve be managed to protect threatened species or left in its natural state?

Preserving Biodiversity Hot Spots

- A **biodiversity hot spot** is a relatively small area with numerous endemic (found nowhere else) and many endangered and threatened species
- The "hottest" biodiversity spots comprise less than 1.5% of Earth's land but house more than 1/3 of all plants and terrestrial vertebrates

Figure 56.19



- Identifying biodiversity hot spots can be problematic
  - Not all taxonomic groups are found in the same spots
  - There is bias toward saving vertebrates and plants
  - Focus on hot spots emphasizes protecting a small fraction of the Earth’s surface
  - Climate change may alter locations of hot spots in the future

Philosophy of Nature Reserves

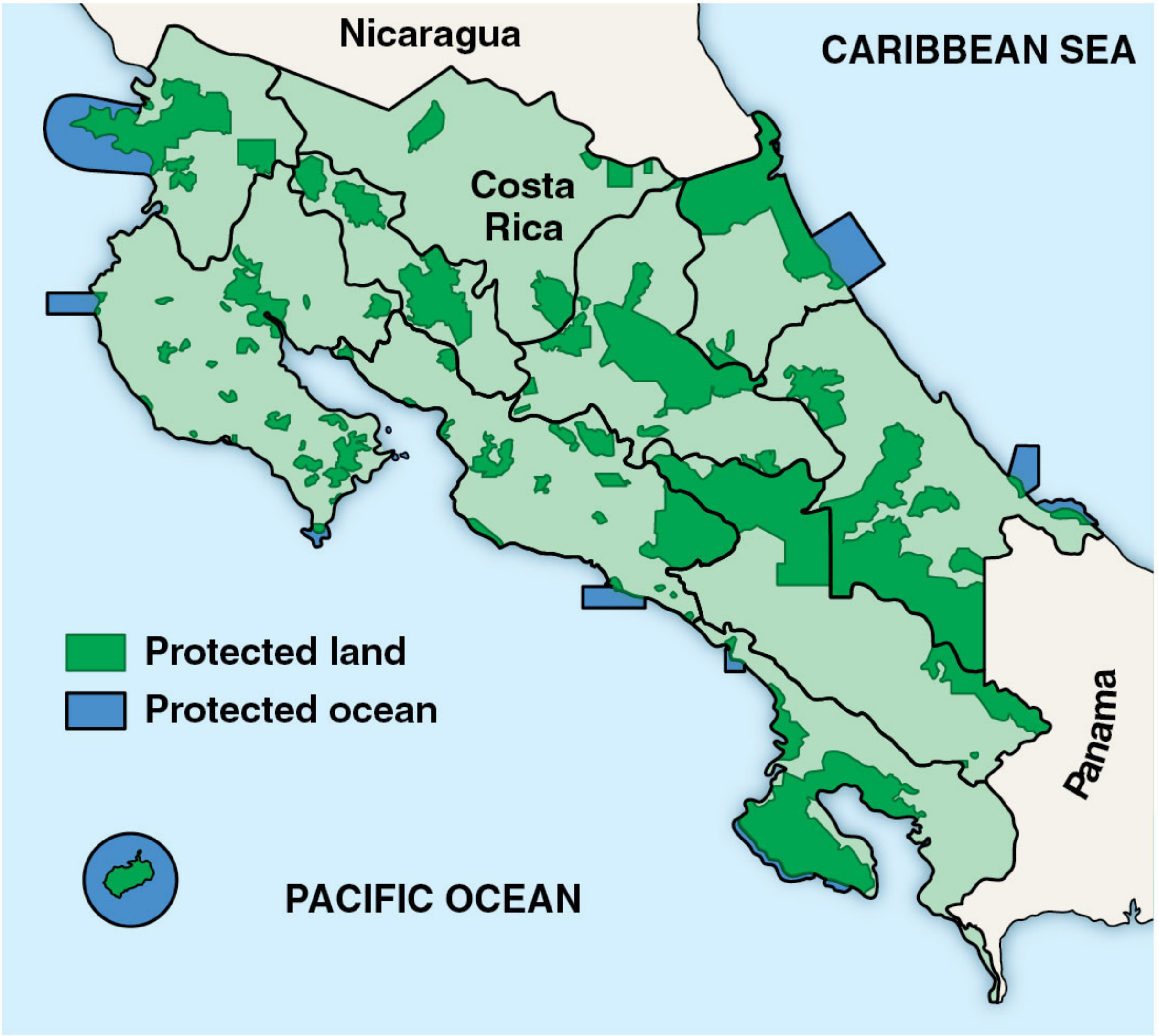
- Nature reserves are biodiversity islands in a sea of habitat altered or degraded by human activity
- Nature reserves must consider disturbances as a functional component of all ecosystems

- An important question is whether to create fewer large reserves or more numerous small reserves
- Large reserves support large, far-ranging animals with low-density populations or species sensitive to habitat edges
- Small, unconnected reserves may slow the spread of disease between populations

Zoned Reserves

- **Zoned reserves** include relatively undisturbed areas surrounded by areas where human activities are unlikely to harm the protected area
- The modified areas surrounding the protected areas serve as buffer zones
- Costa Rica, a world leader in establishing zoned reserves, is divided into 11 Conservation Areas

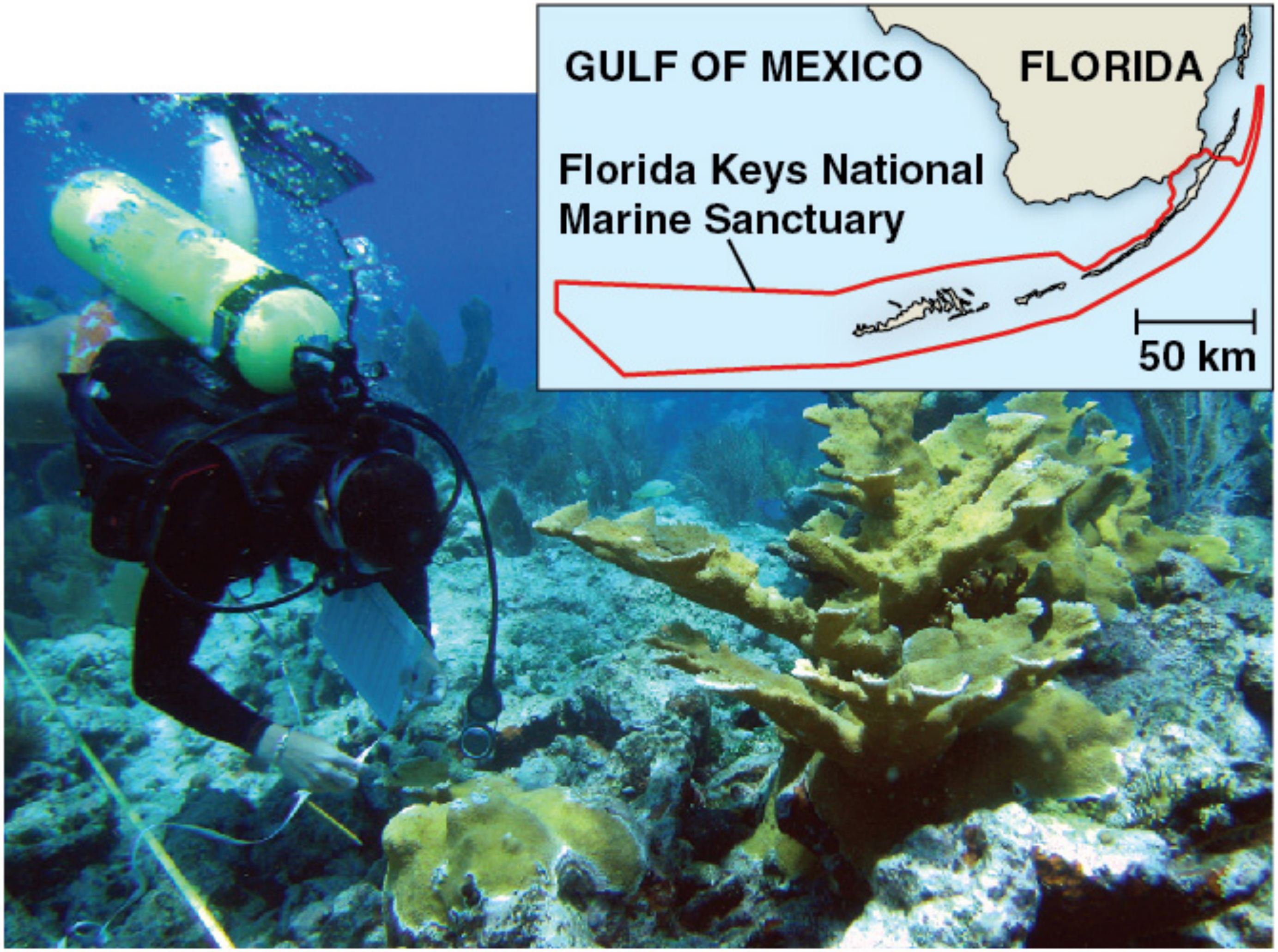
Figure 56.20



Nicaragua
CARIBBEAN SEA
Costa Rica
Protected land
Protected ocean
PACIFIC OCEAN
Panama

- A patchwork of marine reserves off-limits to fishing can increase fish populations within the reserves and improve fishing success in surrounding areas
- Zoned marine reserves established in the United States quickly resulted in the recovery of marine communities in and around the protected areas

Figure 56.21


GULF OF MEXICO
FLORIDA
Florida Keys National Marine Sanctuary
50 km

Video: Coral Reef

Urban Ecology

- The field of **urban ecology** examines organisms and their environment in urban settings
- One critical area of research focuses on quality and flow of water and organisms living in urban streams
- Restoration projects may involve stabilizing stream banks, removing introduced plants, and planting native trees and shrubs

Figure 56.22

CONCEPT 56.4: Earth is changing rapidly as a result of human actions

- The current location of reserves may be unsuitable in the future due to human-caused changes such as
  – Nutrient enrichment
  – Toxin accumulation
  – Climate change
  – Ozone depletion

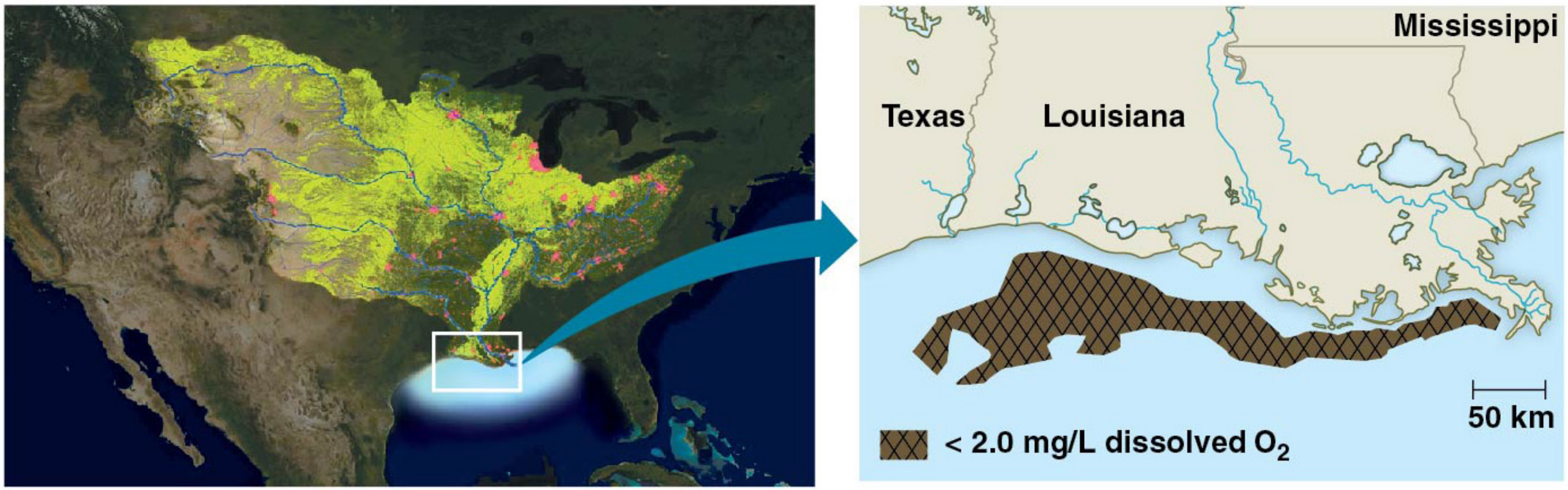
Nutrient Enrichment

- Human activity often removes nutrients from one part of the biosphere and adds them to another
- Harvest of agricultural crops exports nutrients from agricultural areas in crop biomass
- Industrial fertilizers are used to replace lost nutrients to the agricultural ecosystem

- **Critical load** is the amount of added nutrient that can be absorbed by plants without damaging ecosystem integrity
- Nutrients that exceed the critical load leach into groundwater or run off into aquatic ecosystems

- Agricultural runoff and sewage cause phytoplankton blooms in aquatic ecosystems
- When phytoplankton die, oxygen is depleted by their decomposers, resulting in death of aquatic animals
  - For example, the Mississippi River carries nitrogen pollution to the Gulf of Mexico fueling a phytoplankton bloom and massive “dead zone” each summer

Figure 56.23



(a) Nutrients drain from agricultural land (green) and cities (red) through the vast Mississippi watershed to the Gulf of Mexico.

(b) The 2017 dead zone, represented here, was the largest yet measured. It occupied 22,730 km^2 (8,776 mi^2), an area slightly larger than New Jersey.

Toxins in the Environment

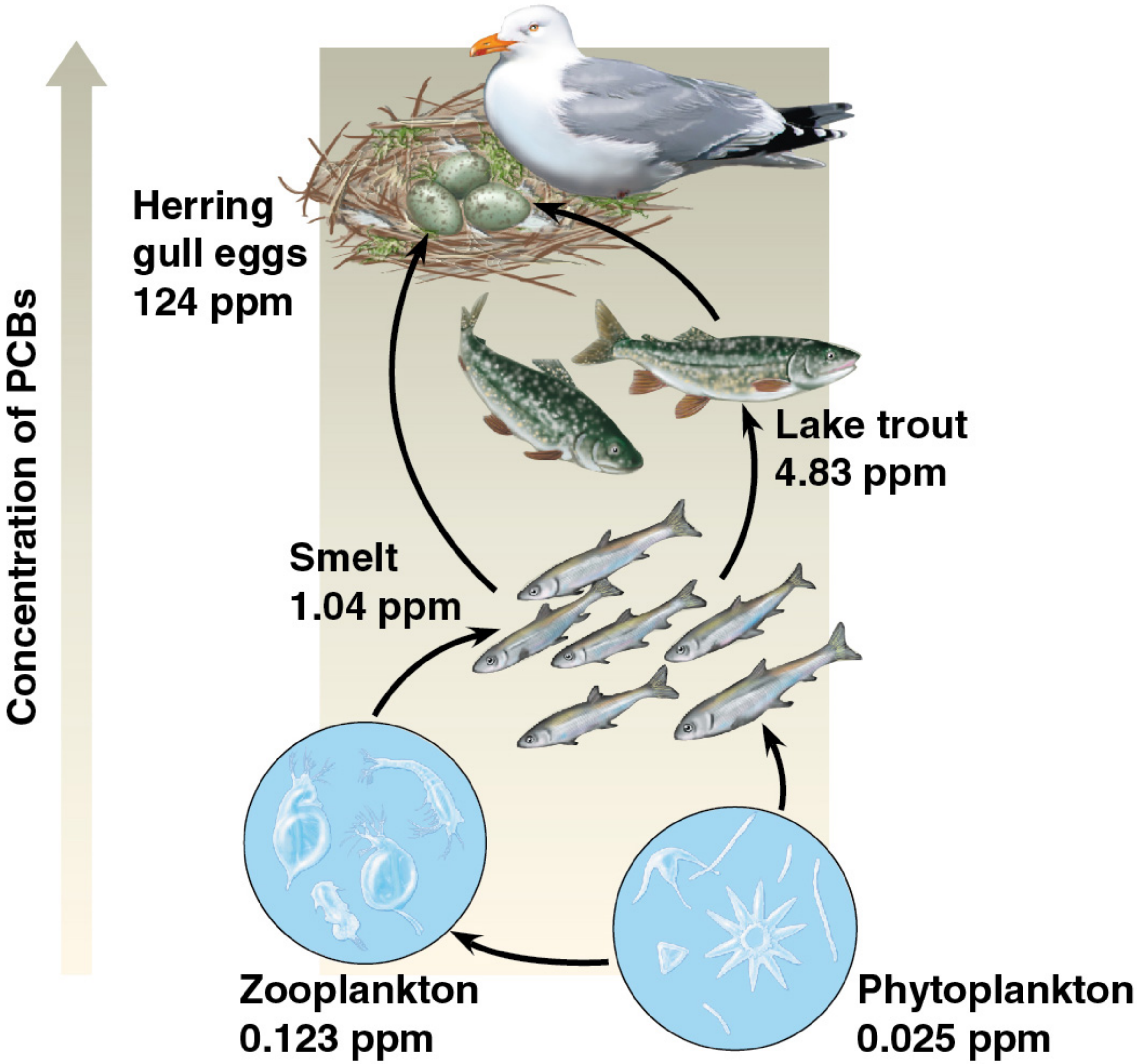
- Humans release many toxic chemicals, including synthetics previously unknown to nature
- Toxins can persist in ecosystems for long periods
- Some toxins are metabolized or excreted, others accumulate in animal tissues, often in fat

- The biomass at any trophic level is produced from a much larger biomass ingested from the level below
- **Biological magnification** occurs when toxins are passed up the food chain and concentrated in organisms at higher trophic levels

Industrial Compounds and Pesticides

- Chlorinated hydrocarbons, such as PCBs, and many pesticides, such as DDT, are subject to biological magnification in ecosystems
  - For example, the concentration of PCBs in herring gull eggs, at the top of the Great Lakes food web, is nearly 5,000 times that in the phytoplankton at the base

Figure 56.24


Concentration of PCBs
Herring
gull eggs
124 ppm
Lake trout
4.83 ppm
Smelt
1.04 ppm
Zooplankton
0.123 ppm
Phytoplankton
0.025 ppm

- Use of DDT grew rapidly following World War II, but by the 1950s its environmental effects became clear
- DDT accumulated in tissues of birds at the top of the food web, interfering with egg shell production
- Weak shells broke under the weight of parents attempting to incubate the eggs
- Dramatic declines in bird populations followed

- In the 1960s, the publication of *Silent Spring*, by Rachel Carson, brought public attention to the environmental effects of DDT
- DDT was banned in the United States in 1971
- Bird populations have recovered dramatically in the years since the ban

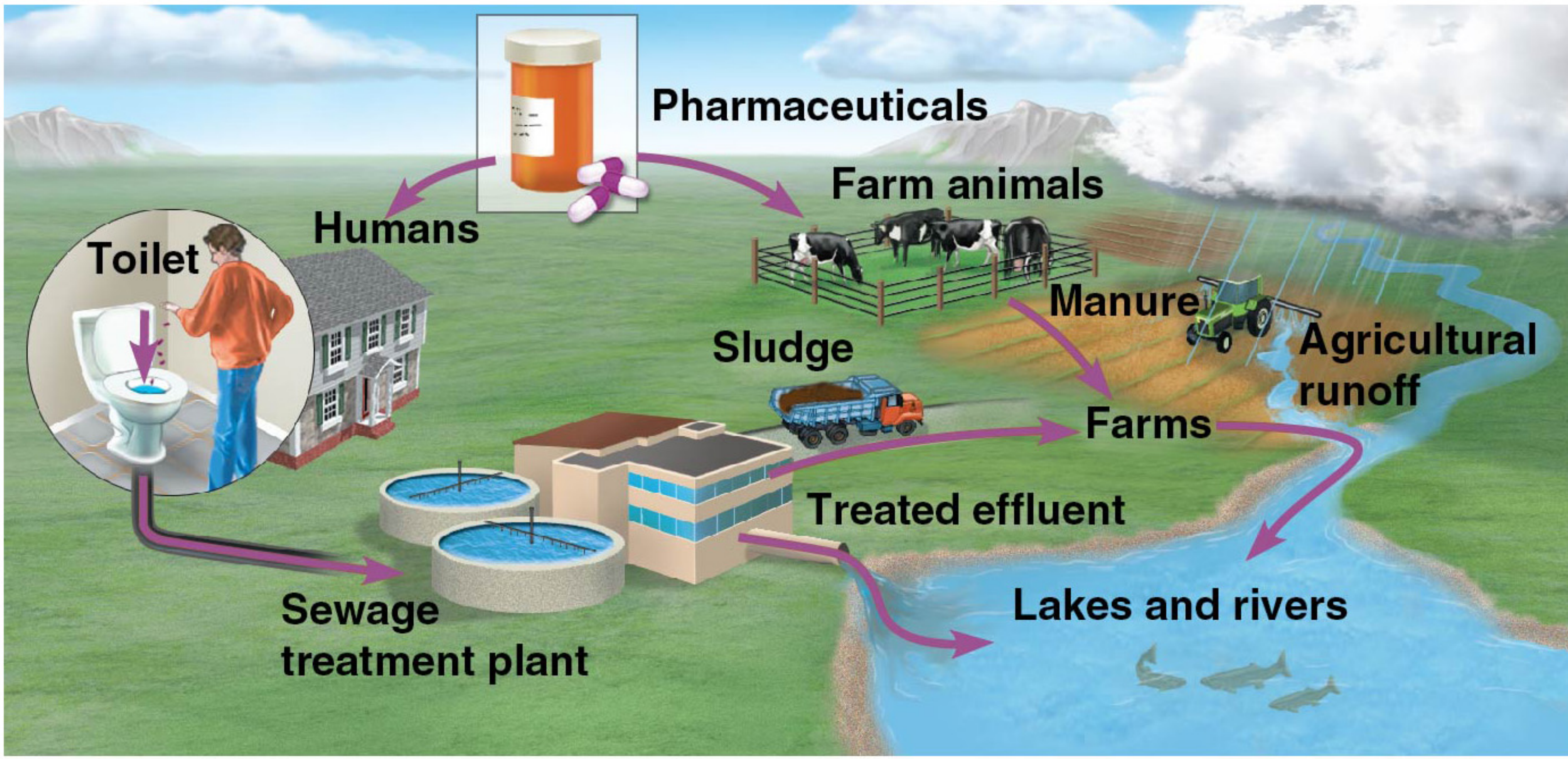
Figure 56.25

- Countries with malaria face a trade-off between using DDT to kill mosquitoes (malarial vectors) and protecting other species
- Many insect species have evolved resistance to DDT
- It must now be applied sparingly and coupled with mosquito netting and other low-technology solutions

Pharmaceuticals

- Pharmaceutical drugs enter freshwater ecosystems through human sewage and agricultural runoff
- Sex steroids, such as the estrogen used in birth control pills, can shift the sex ratio toward females in some species of fish

Figure 56.26



Pharmaceuticals
Humans
Farm animals
Toilet
Manure
Sludge
Agricultural runoff
Farms
Treated effluent
Sewage treatment plant
Lakes and rivers

Plastic Waste

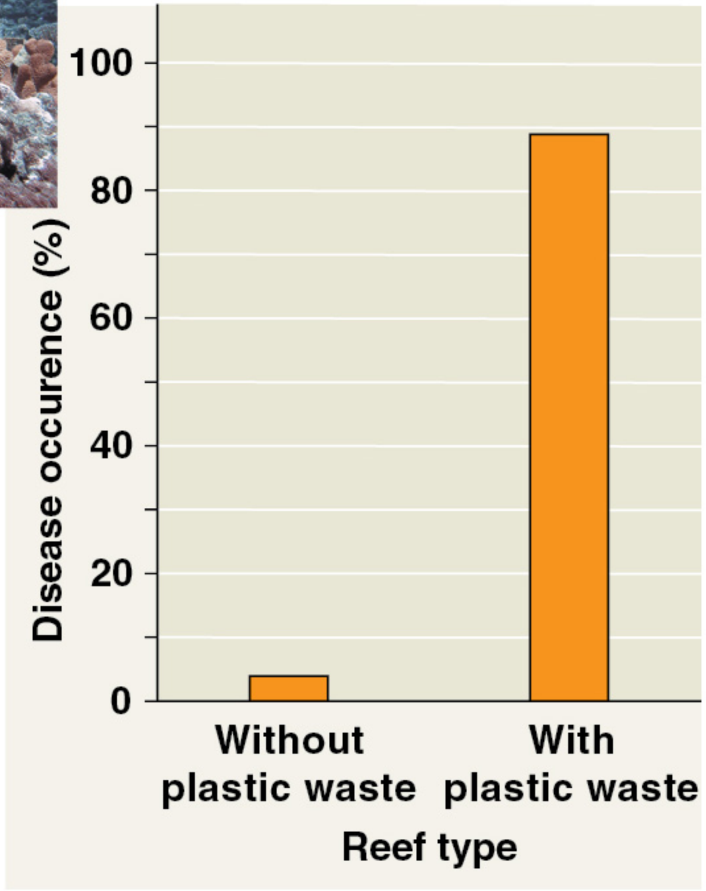
- Plastics are the most common type of marine waste
- About 4.8 to 12.7 million metric tons enter the ocean each year and persist for hundreds of years
- **Microplastics**, particles < 5 mm in size, are formed from the breakdown of larger pieces by wave action and UV light

- Many marine animals including birds, mammals, turtles, and fish die after mistaking plastic debris for food

Figure 56.27

- Plastic contaminated coral reefs have higher rates of disease
  - Bacterial pathogens are transported to reefs by “hitchhiking” on plastic waste
  - Plastic blocks light and oxygen penetration, reducing disease resistance in corals

Figure 56.28



Disease occurence (%)
100
80
60
40
20
0
Without plastic waste
With plastic waste
Reef type

- Microplastics now contaminate all of the oceans and are found in every type of marine food chain
- About 25% of supermarket fish in the United States contain microplastics in their guts
- Terrestrial and freshwater ecosystems are also polluted by microplastics
- Microplastics may be transported in the atmosphere

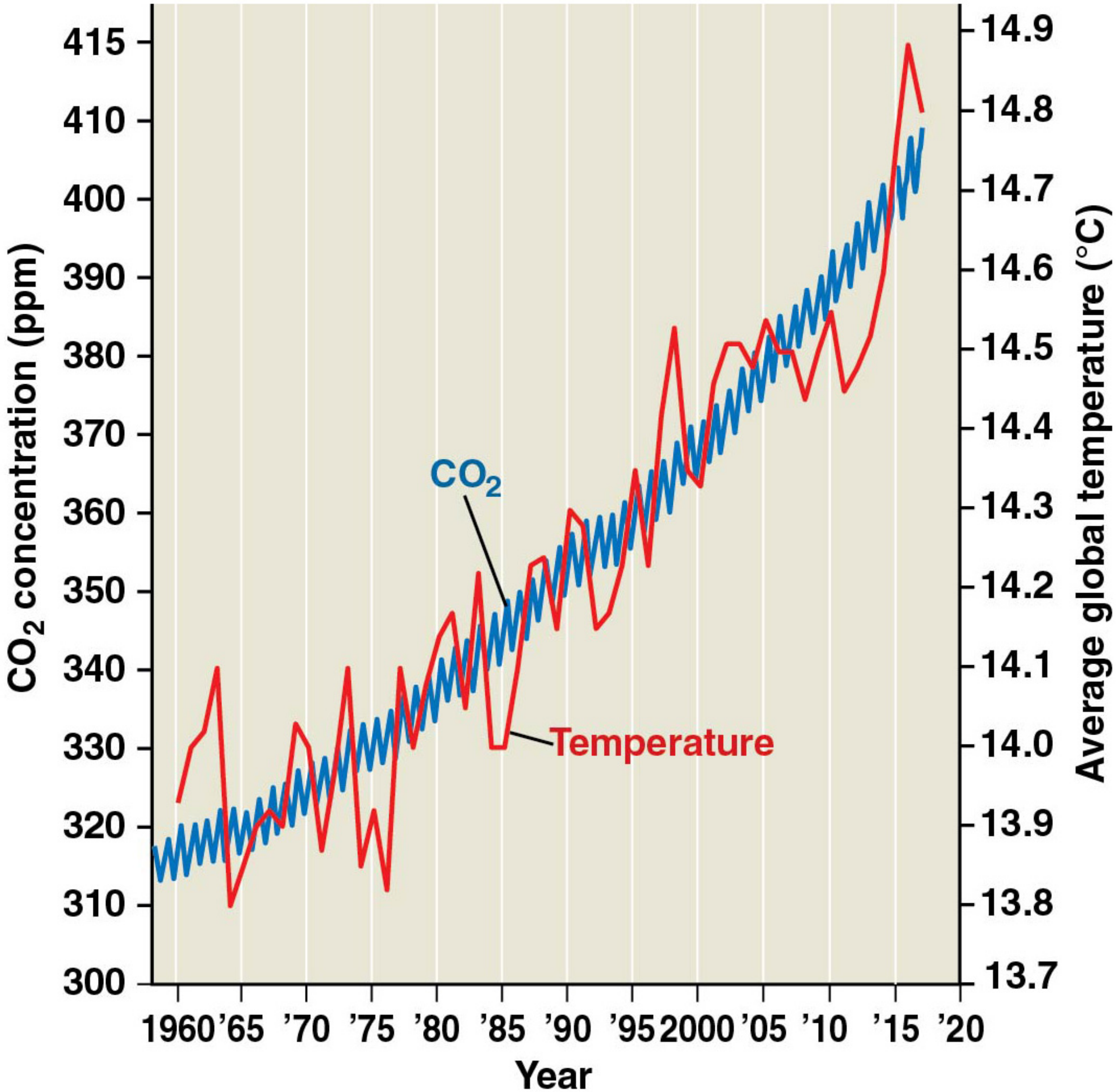
Greenhouse Gases and Climate Change

- **Climate change** is a directional change to the global climate that lasts for three decades or more
- Human activities are driving climate change through the release of gaseous waste into the atmosphere

Rising Atmospheric CO_2 Levels

- The concentration of atmospheric CO_2 has been steadily increasing over the past 170 years
- By 2018, CO_2 levels had increased by more than 50% since the mid-19th century
- Burning fossil fuels and deforestation are the major factors driving this increase

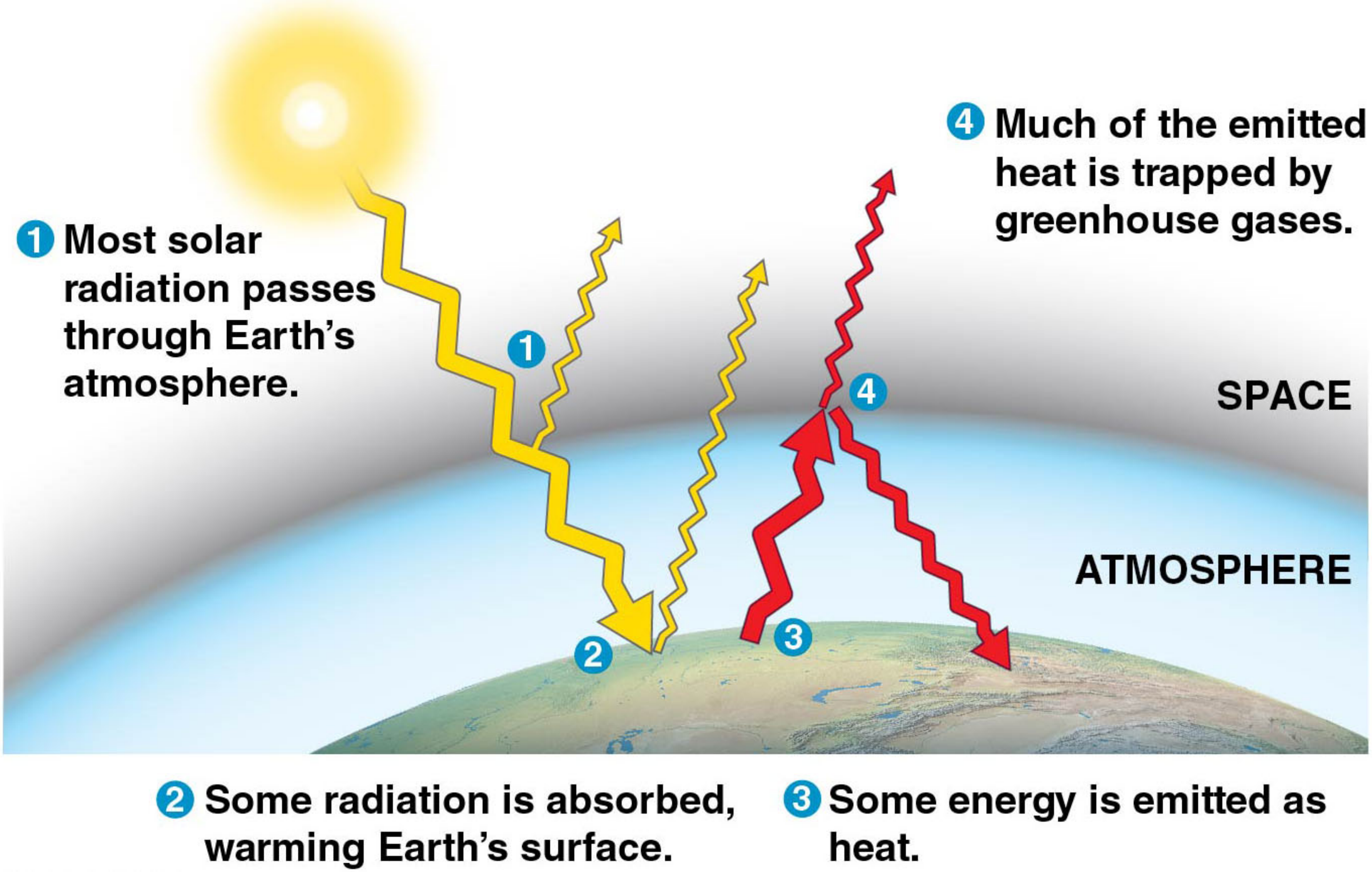
Figure 56.29



CO2 concentration (ppm)
415
410
400
390
380
370
360
350
340
330
320
310
300
CO2
Temperature
14.9
14.8
14.7
14.6
14.5
14.4
14.3
14.2
14.1
14.0
13.9
13.8
13.7
Average global temperature (°C)
1960 ’65 ’70 ’75 ’80 ’85 ’90 ’95 2000 ’05 ’10 ’15 ’20
Year

- Rising CO_2 is a concern due to its link to increased global temperature
- CO_2 and other greenhouse gases reflect infrared radiation back toward Earth, warming the surface, and causing the **greenhouse effect**

Figure 56.30

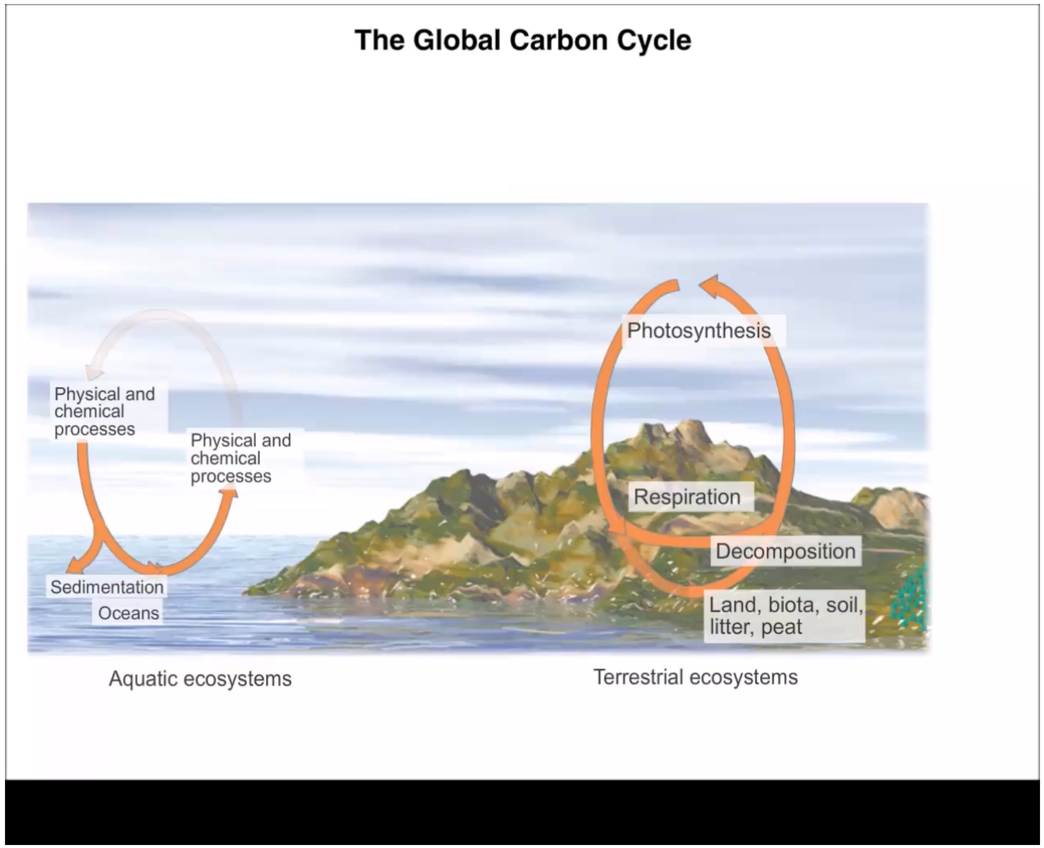


1 Most solar radiation passes through Earth's atmosphere.
1
4 Much of the emitted heat is trapped by greenhouse gases.
4
SPACE
ATMOSPHERE
2
3
2 Some radiation is absorbed, warming Earth's surface.
3 Some energy is emitted as heat.

- The accumulation of greenhouse gases is causing rapid warming
- The average global temperature has increased by 0.9ºC (1.6ºF) since 1900
- Of the 19 warmest years on record, 18 occurred since 2001, with 2016 being the warmest year ever

- As the planet warms, wind and precipitation patterns are also shifting
- Extreme weather events (such as droughts, heat waves, and hurricanes) are becoming more common

Animation: The Global Carbon Cycle and the Greenhouse Effect



Biological Effects of Climate Change

- Climate change has reduced geographic ranges and caused population declines in hundreds of species
  - For example, the geographic distributions of 67 bumblebee species have decreased in size
- Organisms that cannot disperse rapidly or find suitable habitat are less likely to persist

- Northern coniferous forests and tundra show the strongest effects of global warming
- Melting snow and ice uncover darker surfaces that reflect less radiation, causing warming
- Summer sea ice habitat for polar bears, seals, and seabirds may be lost from the Arctic within a few decades

- Frequent drought and high temperatures increase the rate of tree deaths and fires in coniferous forests
  - For example, in recent decades, twice the usual area of the boreal forest has burned in forest fires

- Many other ecosystems have been affected by climate change
  - In Europe and Asia, plants are producing leaves earlier in spring
  - Two-thirds of Australia’s Great Barrier Reef is severely degraded following heat waves in 2016 and 2017

Figure 56.31 Make Connections: Climate change has effects at all levels of biological organization

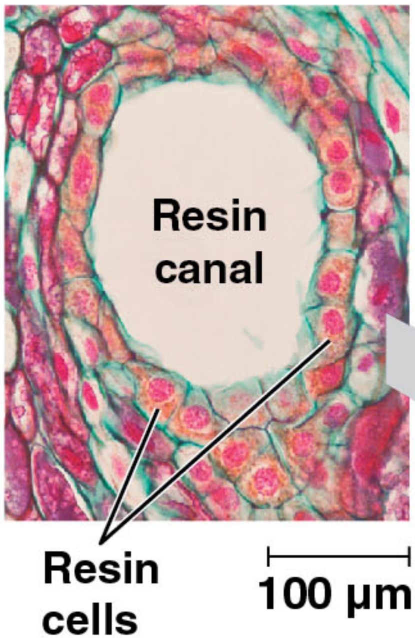
Climate Change Has Effects at All Levels of Biological Organization

Effects on Cells

- Increasing temperature affects rates of enzymatic reactions and impairs cellular defense responses
  - For example, climate change has reduced the ability of pine trees to defend against mountain pine beetle in western North America

Figure 56.31a

Effects on Cells



Resin cells produce less defensive resin in trees that are stressed by drought and rising temperatures.

Rising temperatures have shortened how long it takes beetles to mature and reproduce.

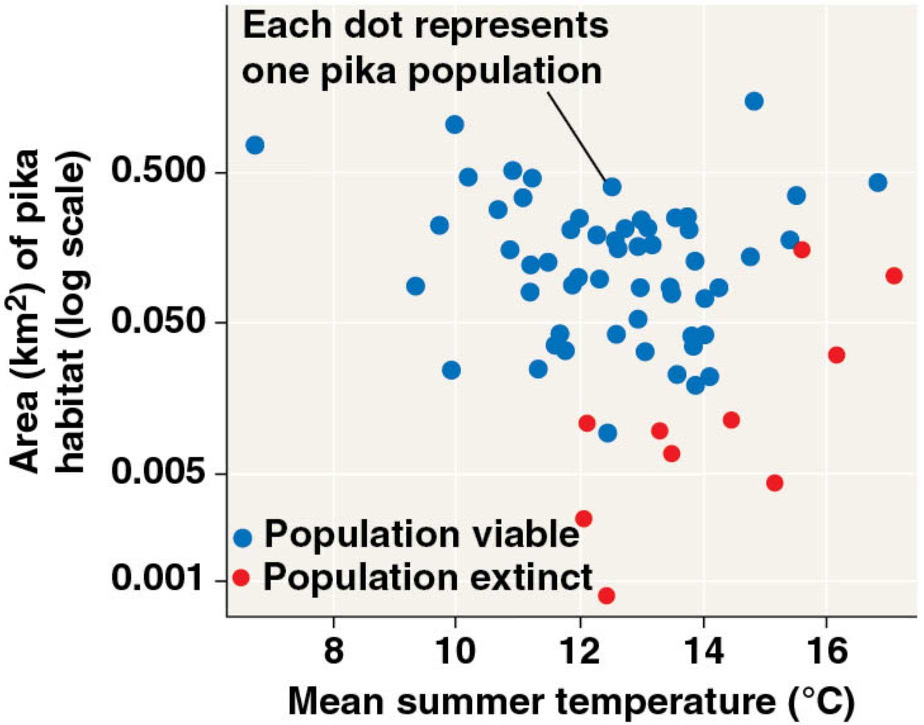
An aerial view shows the scope of destruction due to mountain pine beetles; dead trees appear orange and red.

Effects on Individual Organisms

- Global warming has increased the risk of overheating in some species, leading to reduced food intake and reproductive failure
  - For example, the American pika will die if its body temperature rises 3°C above resting temperature
  - Climate change has created conditions in some regions where this happens quickly

Effects on Individual Organisms

As temperatures rise, American pikas spend more time in their burrows to escape the heat, and less time foraging for food.



Most pika extinctions occur at sites with high summer temperatures and a small area of habitat.

Effects on Populations

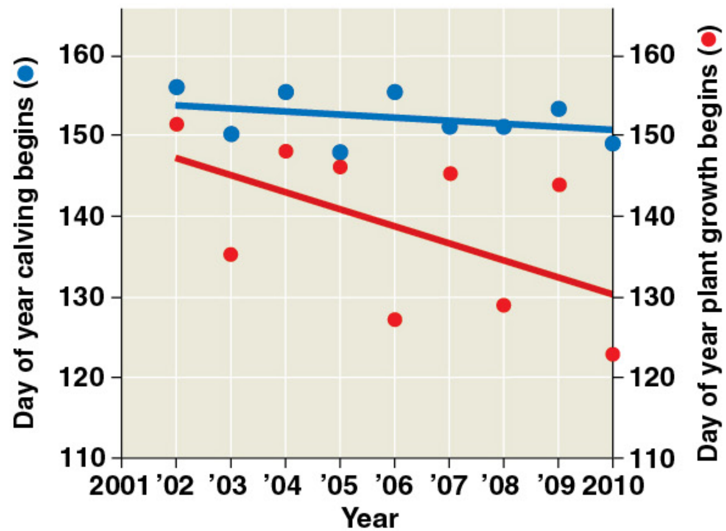
- Climate change has caused changes in population size and timing of growth, reproduction, and migration in some species
- Some populations experience food shortages and reduction in survival and reproductive success
  - For example, researchers have found a link between rising temperature and Arctic caribou population declines

Figure 56.31c

Effects on Populations

Caribou populations migrate north in the spring to give birth and to eat sprouting plants.

Alpine chickweed is an early-flowering plant on which caribou depend.



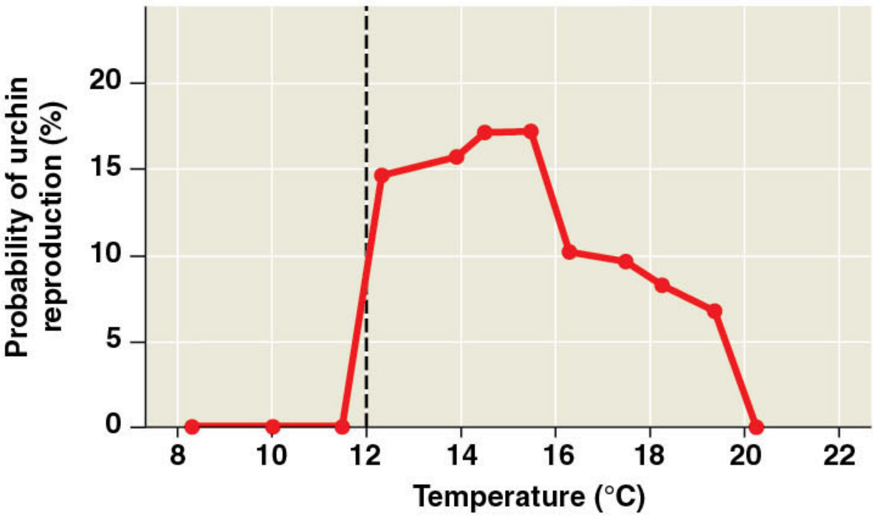
Earlier spring plant growth has resulted in food shortages and a fourfold drop in caribou offspring production.

Effects on Communities and Ecosystems

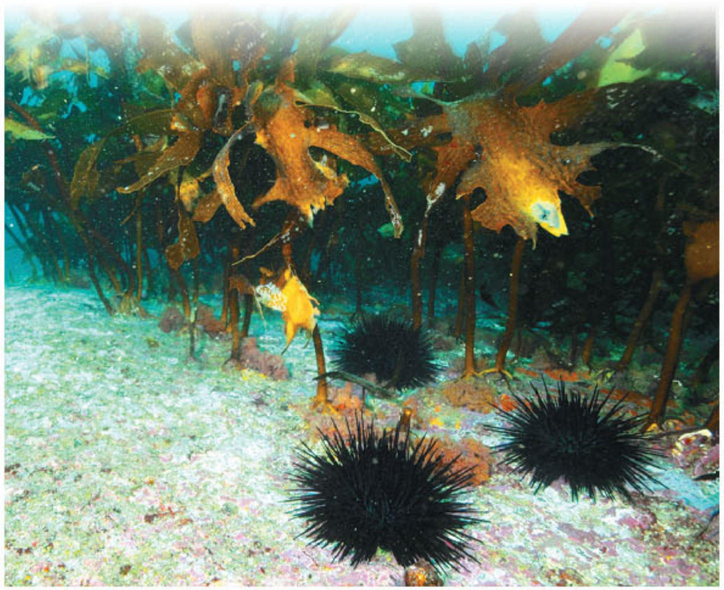
- Species migration in response to climate change has caused dramatic change in ecological communities
- Primary production and nutrient cycling have also been affected
  - For example, marine communities in southern Australia have been devastated by a sea urchin invasion

Figure 56.31d

Effects on Communities and Ecosystems



The sea urchin *Centrostephanus rodgersii* requires water temperatures above 12°C to reproduce successfully. Warming ocean waters have enabled the urchin to expand its range to the south.



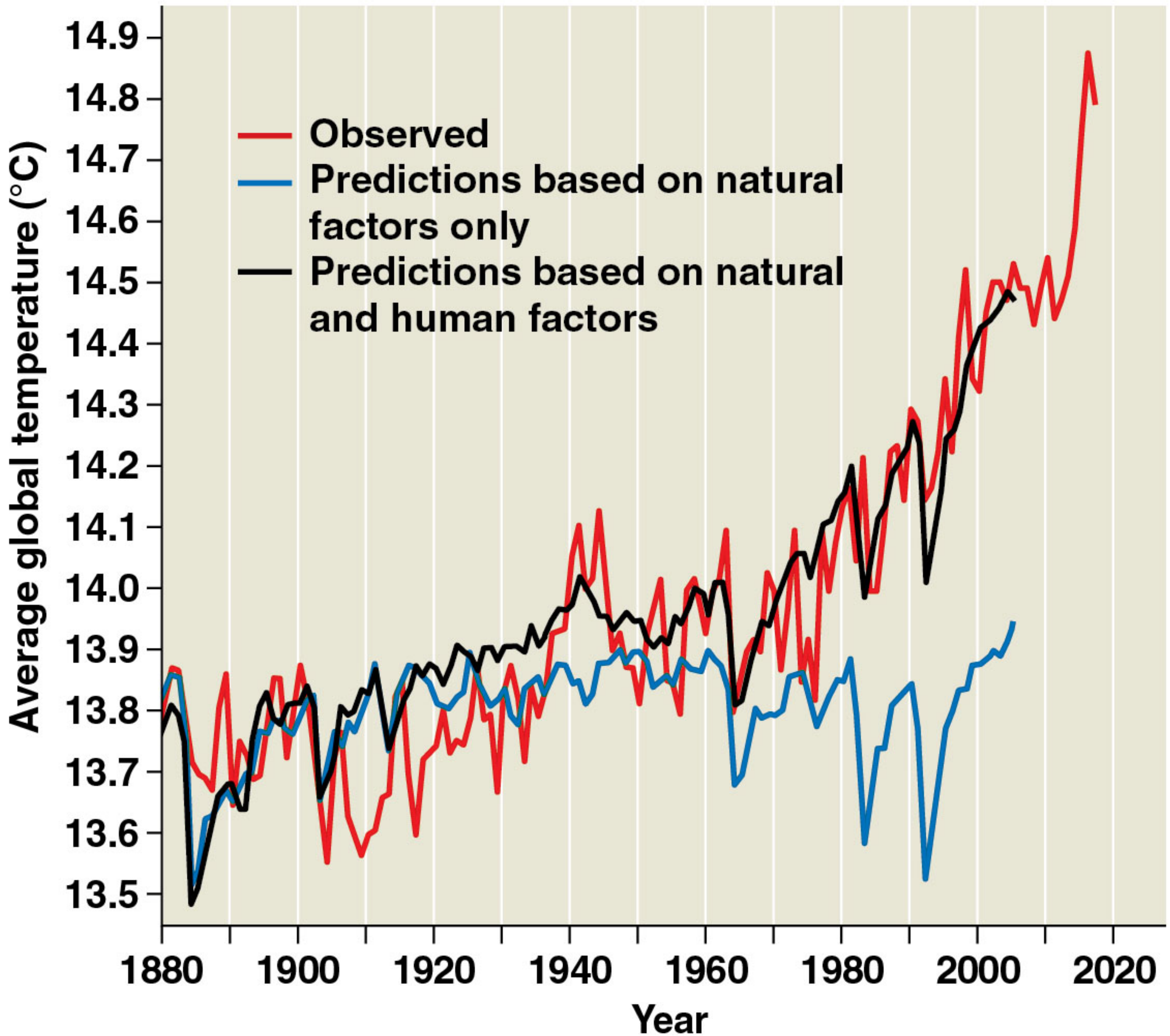
As the sea urchin expands its range, it destroys high-diversity kelp communities, leaving "urchin barrens" in its wake.

Modeling Climate Change

- Global models predict an additional 3°C (5°F) rise in temperature by the end of the 21st century
- The models are constructed using data on factors that affect surface absorption of solar radiation
- Natural factors affecting absorption include the 11-year solar cycle and volcanic explosions

- Human activities also have a major impact on the absorption of solar radiation
  - The release of greenhouse gases through burning fossil fuels increases absorption, leading to warming
  - Release of dust by plowing fields decreases absorption, leading to cooling

Figure 56.32



Observed
Predictions based on natural factors only
Predictions based on natural and human factors
Average global temperature (°C)
14.9
14.8
14.7
14.6
14.5
14.4
14.3
14.2
14.1
14.0
13.9
13.8
13.7
13.6
13.5
1880
1900
1920
1940
1960
1980
2000
2020
Year

- Climate models can be used to perform experiments to determine outcomes of changing CO_2 emissions
  - If we continue with current CO_2 emissions, global temperature will be 4°C higher in 2100 than 1900
  - If we stop emissions completely, the temperature would still be 1.5°C higher in 2100 than 1900

Finding Solutions to Address Climate Change

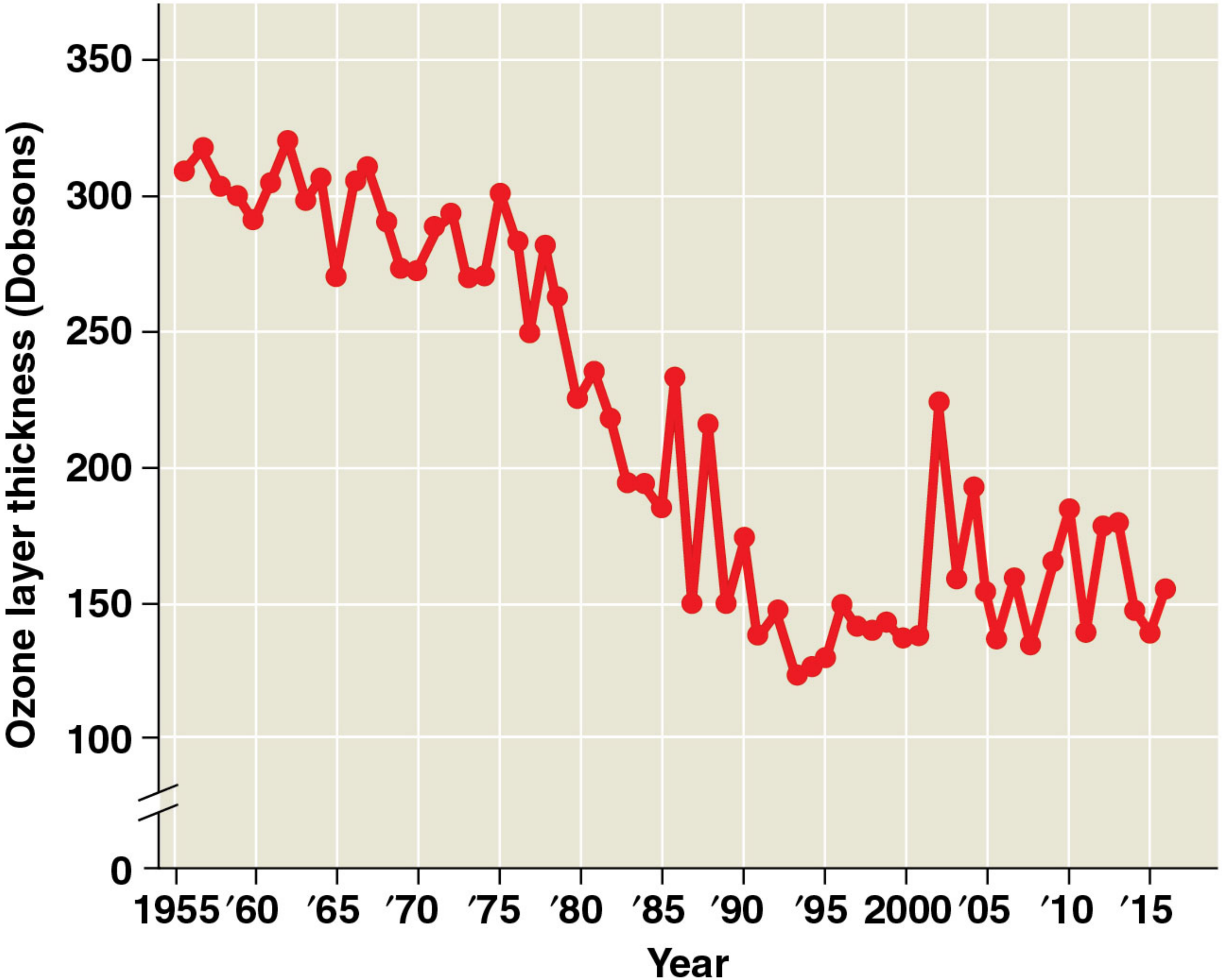
- Global warming can be slowed by reducing energy use and converting to renewable sources of energy
- Progress was made through the 2015 ratification of the Paris Agreement, an international agreement to reduce CO_2 emissions
- The 2020 withdrawal by the United States highlights the disconnect between knowledge and action

- The evidence for human caused climate change is overwhelming
- Failure to act now will result in negative consequences for humanity and all life on Earth

Depletion of Atmospheric Ozone

- Atmospheric ozone (O_3) protects living things from the damaging effects of UV radiation
- The springtime ozone layer over Antarctica has thinned substantially since the mid-1970s

Figure 56.33

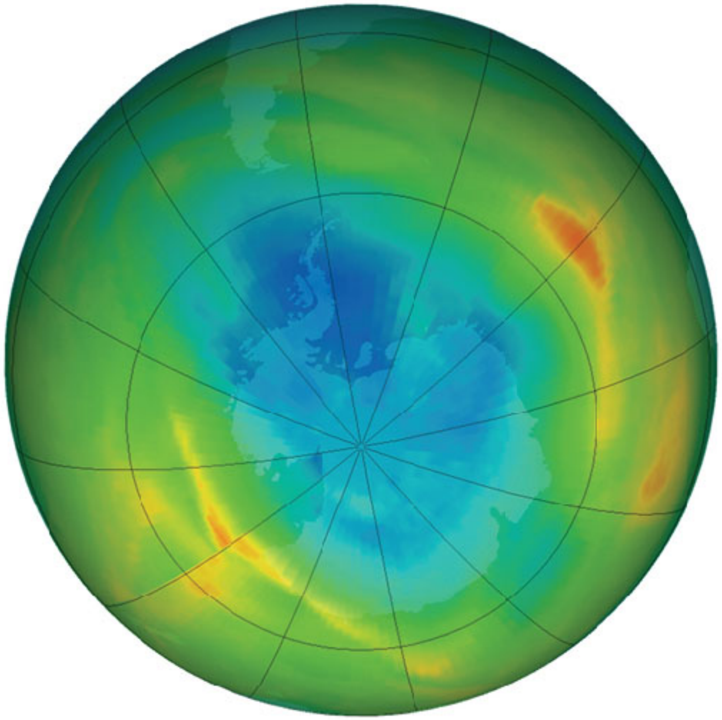


Ozone layer thickness (Dobsons)
350
300
250
200
150
100
0
1955
′60
′65
′70
′75
′80
′85
′90
′95
2000
′05
′10
′15
Year

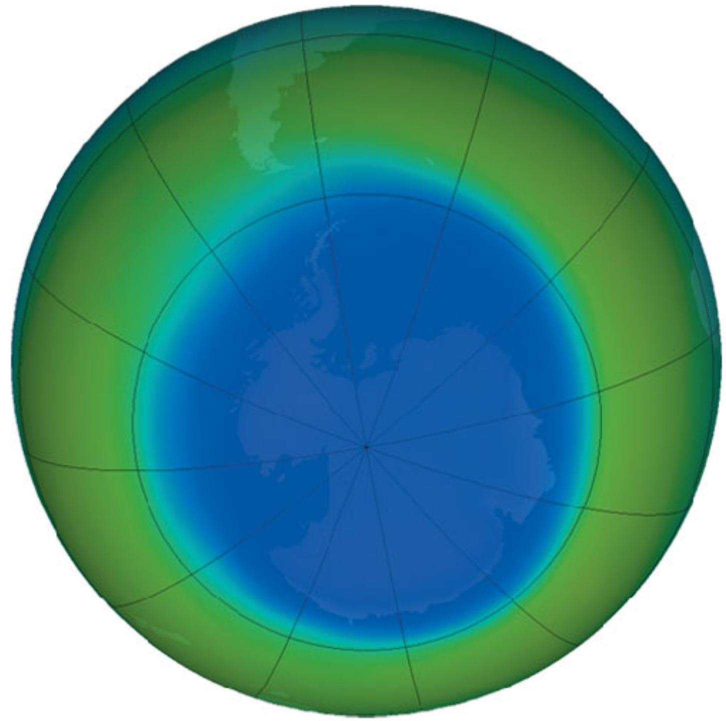
- Industrial chlorofluorocarbons (CFCs) are primarily responsible for destroying atmospheric ozone
- Chlorine atoms released from CFCs in the atmosphere react with O_3 to produce O_2
- Chlorine atoms are recycled in subsequent reactions and continue to react with other O_3 molecules

- The thinning of the ozone layer is most apparent over Antarctica in the spring
- Ozone levels have decreased 2–10% at mid-latitudes during the past 20 years

Figure 56.34



September 1979



September 2018

- Ozone depletion increases the intensity of UV rays reaching Earth's surface
- Severe consequences are expected for living things
  - For example, increases in lethal and nonlethal forms of skin cancer and cataracts in humans
  - Decreased growth and increased DNA damage in phytoplankton

- Ozone depletion has slowed since signing of the Montreal Protocol, an international agreement regulating use of ozone-depleting chemicals
- The effects of chlorine molecules already in the atmosphere will continue for at least 50 years

CONCEPT 56.5: Sustainable development can improve human lives while conserving biodiversity

- Preserving all habitat patches is not feasible
- Ecologists use the concept of sustainability as a tool to establish long-term conservation priorities

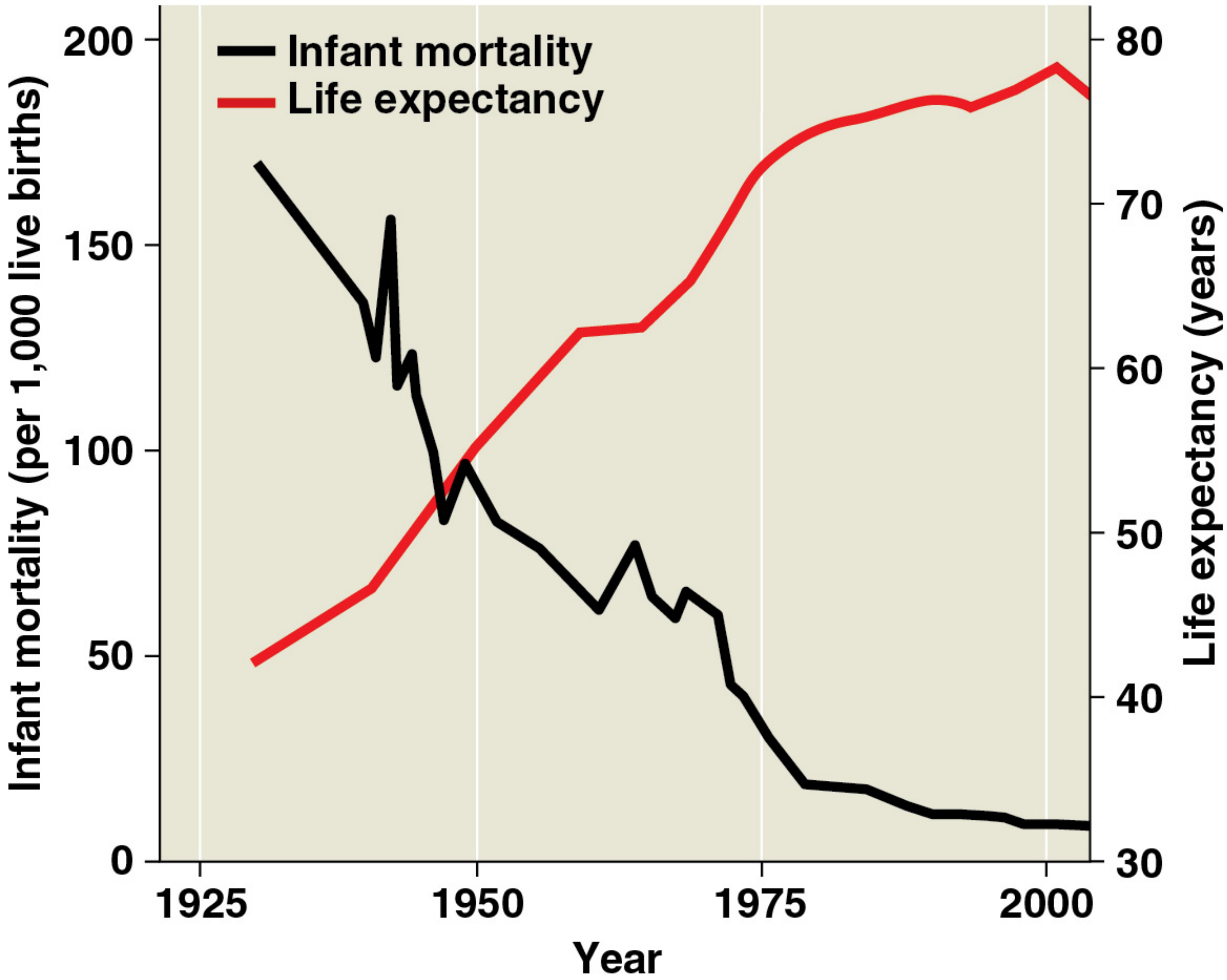
Sustainable Development

- **Sustainable development** meets today's needs without limiting resources for future generations
- Including long-term costs of consumption into decision-making can help clarify the value of ecosystem services

Case Study: *Sustainable Development in Costa Rica*

- Conservation success in Costa Rica required partnerships between government, nongovernmental organizations (NGOs), and private citizens
- Living conditions (infant mortality, life expectancy, literacy rate) improved with ecological conservation

Figure 56.35



Infant mortality
Life expectancy
Infant mortality (per 1,000 live births)
0
50
100
150
200
Life expectancy (years)
30
40
50
60
70
80
1925
1950
1975
2000
Year

The Future of the Biosphere

- Our current lives reflect remnants of our ancestral attachment to nature and the diversity of life
- Biophilia may be an innate product of natural selection due to our dependence on the environment
- Appreciation of life guides the field of biology today

Figure 56.36

(a) Detail of animals in a 17,000-year-old cave painting, Lascaux, France

(b) A 30,000-year-old ivory carving of a water bird, found in Germany

(c) Nature lovers on a wildlife-watching expedition

(d) A young biologist holding a songbird

Figure 56.UN01a

1969	**324.6**	**1989**	**353.1**	**2009**	**387.4**
1970	**325.7**	**1990**	**354.4**	**2010**	**389.9**
1971	**326.3**	**1991**	**355.6**	**2011**	**391.7**
1972	**327.5**	**1992**	**356.5**	**2012**	**393.9**
1973	**329.7**	**1993**	**357.1**	**2013**	**396.5**
1974	**330.2**	**1994**	**358.8**	**2014**	**398.7**
1975	**331.1**	**1995**	**360.8**	**2015**	**400.8**
1976	**332.0**	**1996**	**362.6**	**2016**	**404.2**
1977	**333.8**	**1997**	**363.7**	**2017**	**406.6**
1978	**335.4**	**1998**	**366.7**	**2018**	**408.5**

Data from National Oceanic & Atmospheric Administration, Earth System Research Laboratory, Global Monitoring Division.

Figure 56.UN01b

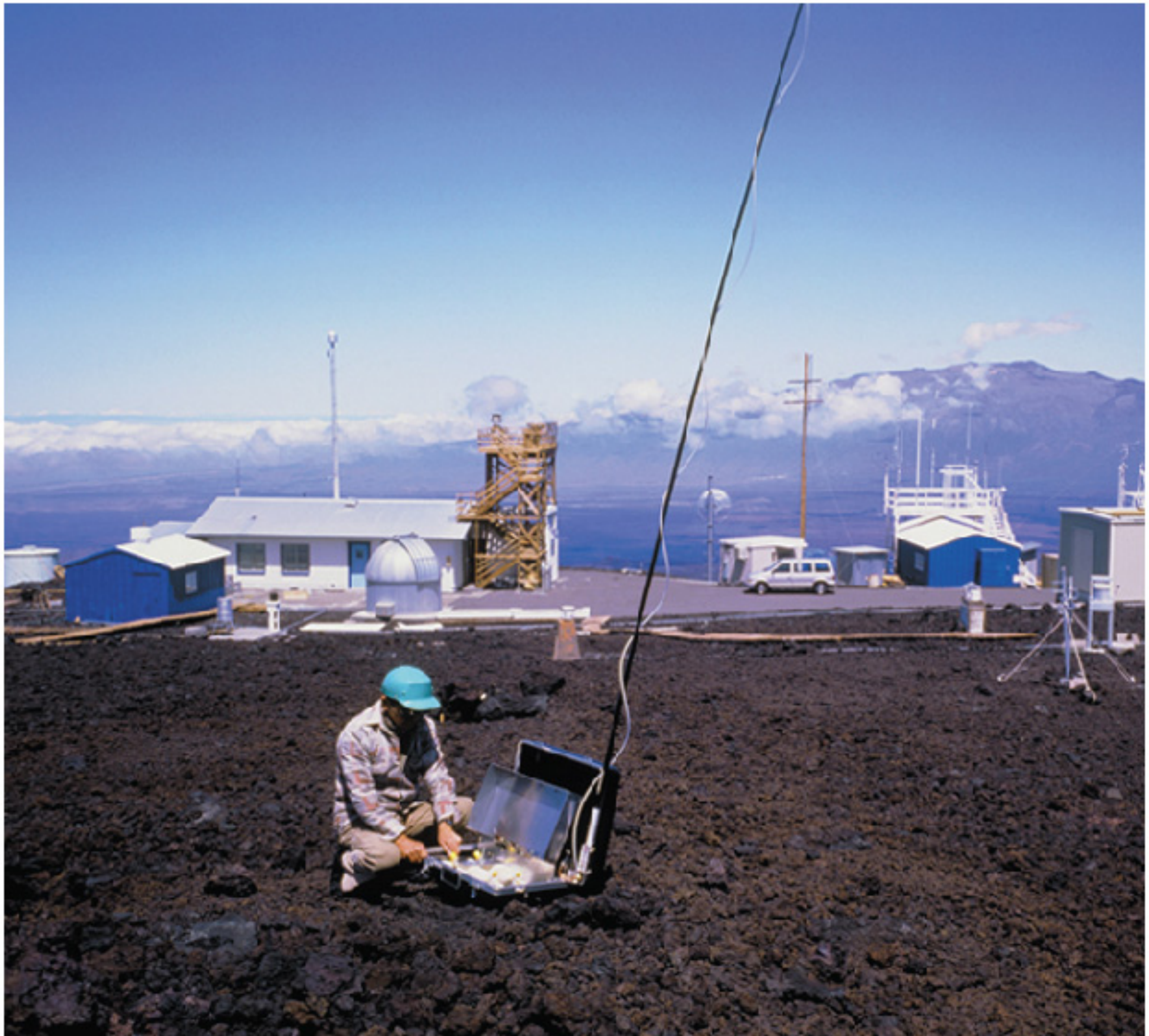


Figure 56.UN02

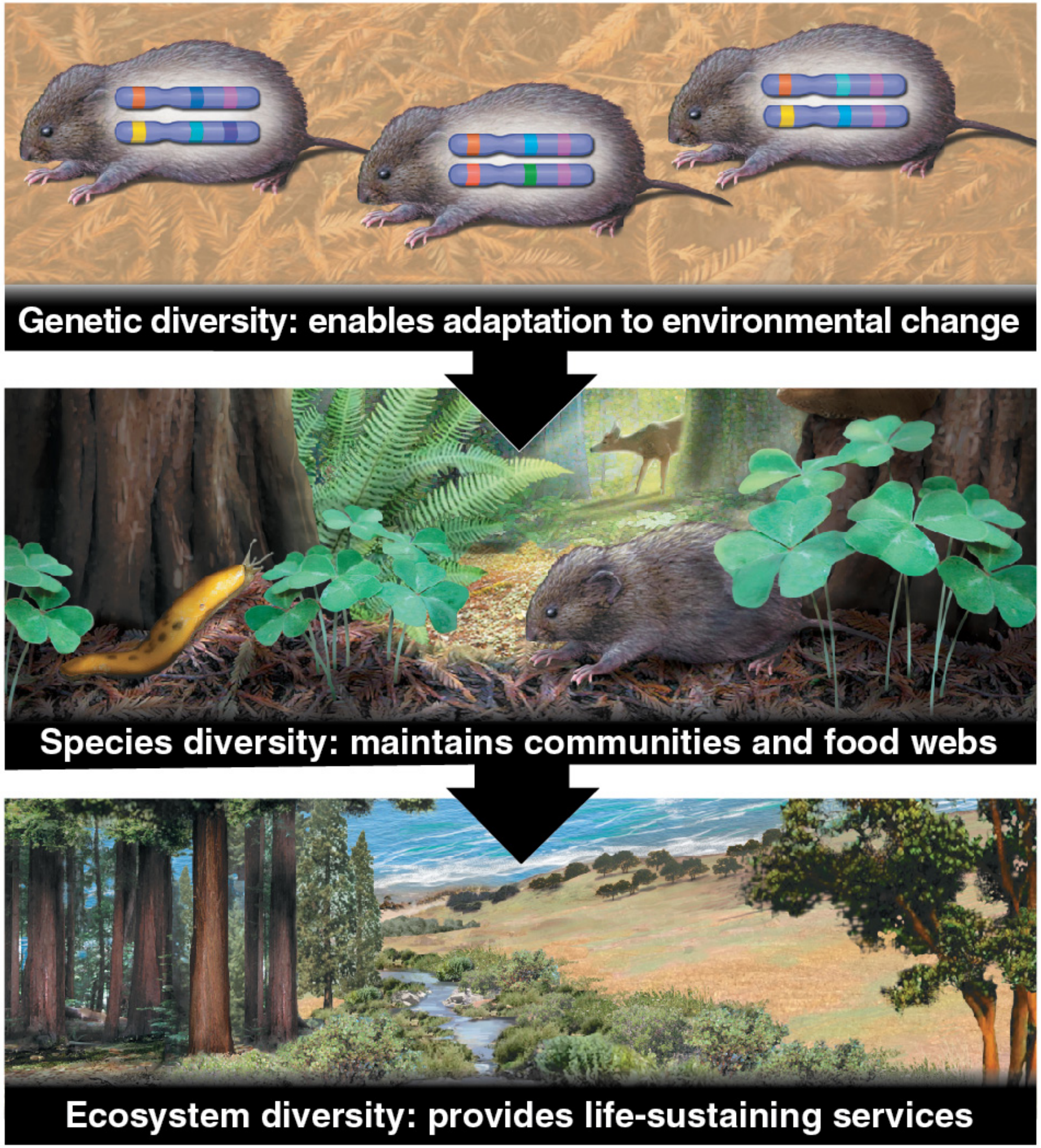


Figure 56.UN03