Chapter 56

Conservation Biology and Restoration Ecology

PowerPoint® Lecture Presentations for

Biology

Eighth Edition

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Overview: Striking Gold

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

Fig. 56-1

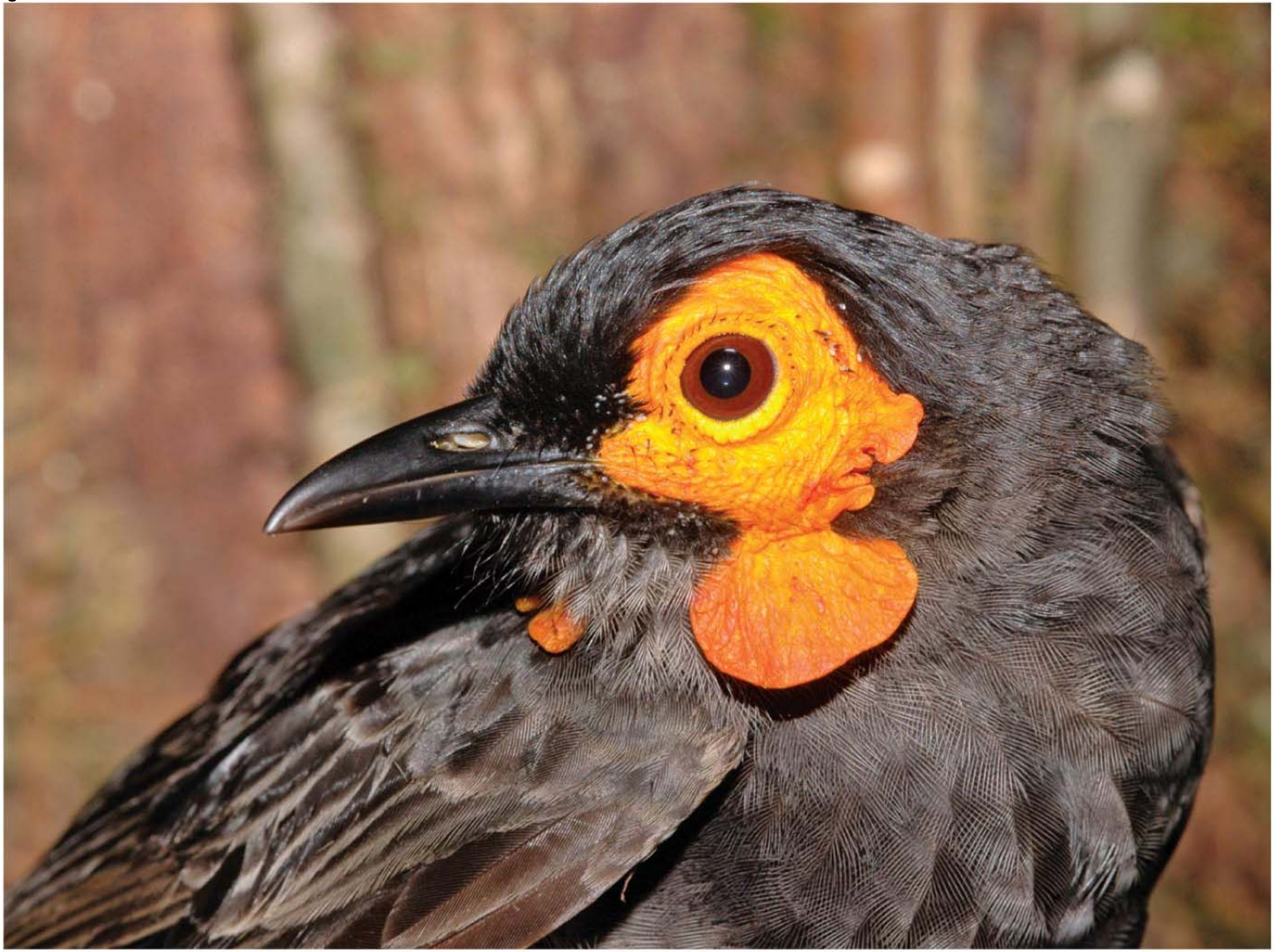


Fig. 56-2

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

- **Restoration ecology** applies ecological principles to return degraded ecosystems to conditions as similar as possible to their natural state

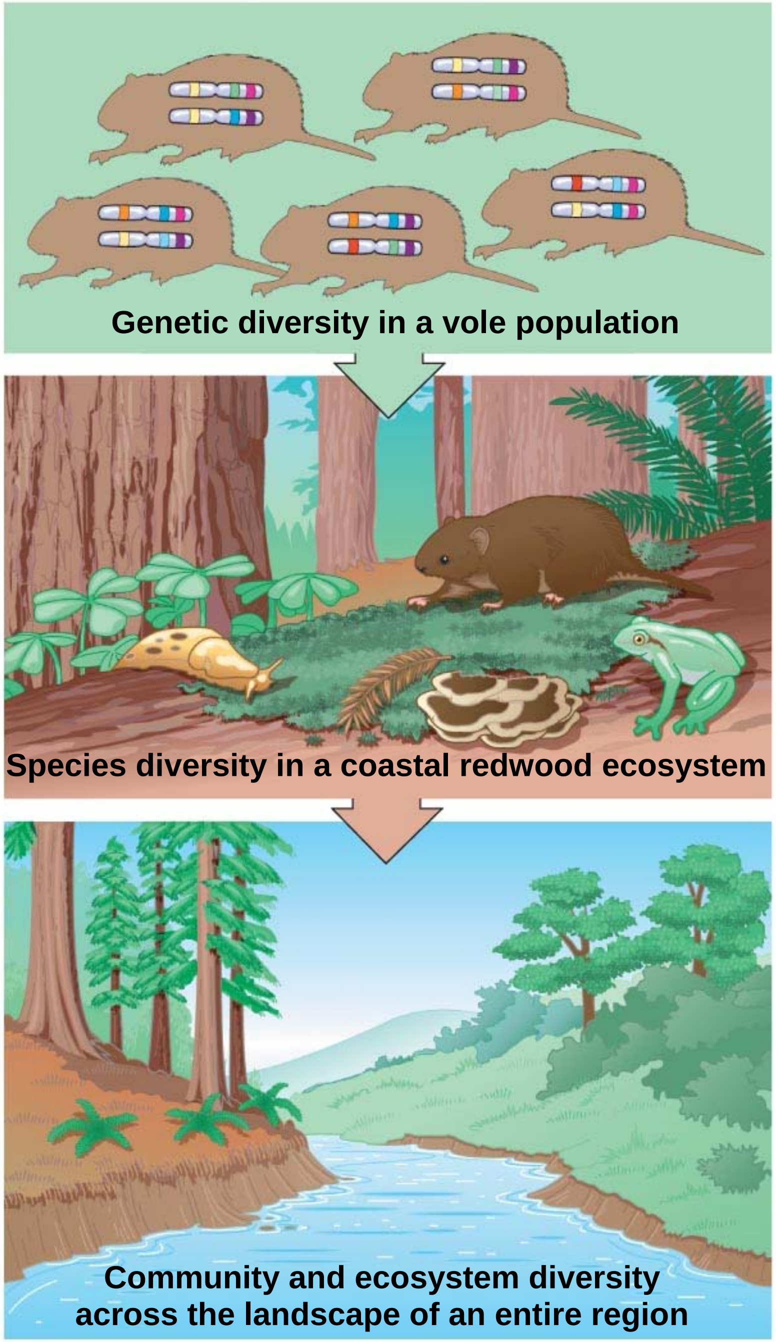
Concept 56.1: Human activities threaten Earth's biodiversity

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

Three Levels of Biodiversity

- Biodiversity has three main components:
  - Genetic diversity
  - Species diversity
  - Ecosystem diversity

Fig. 56-3


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

Species Diversity

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

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

Fig. 56-4

(a) Philippine eagle

(b) Yangtze River dolphin

(c) Javan rhinoceros

Fig. 56-4a

(a) Philippine eagle

Fig. 56-4b

(b) Yangtze River dolphin

Fig. 56-4c

(c) Javan rhinoceros

Ecosystem Diversity

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

Fig. 56-5

Biodiversity and Human Welfare

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

Benefits of Species and Genetic Diversity

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

Fig. 56-6

- The loss of species also means loss of genes and genetic diversity
- The enormous genetic diversity of organisms has potential for great human benefit

Ecosystem Services

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

Three Threats to Biodiversity

- Most species loss can be traced to three major threats:
  - Habitat destruction
  - Introduced species
  - Overexploitation

Habitat Loss

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

Fig. 56-7

Introduced Species

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

- Sometimes humans introduce species by accident, as in case of the brown tree snake arriving in Guam as a cargo ship “stowaway”

Fig. 56-8

(a) Brown tree snake **(b) Kudzu**

Fig. 56-8a

(a) Brown tree snake

Fig. 56-8b

(b) Kudzu

- Humans have deliberately introduced some species with good intentions but disastrous effects
- An example is the introduction of kudzu in the southern United States

Overexploitation

- *Overexploitation* is human harvesting of wild plants or animals at rates exceeding the ability of populations of those species to rebound
- Overexploitation by the fishing industry has greatly reduced populations of some game fish, such as bluefin tuna

Fig. 56-9

- DNA analysis can help conservation biologists to identify the source of illegally obtained animal products

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

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

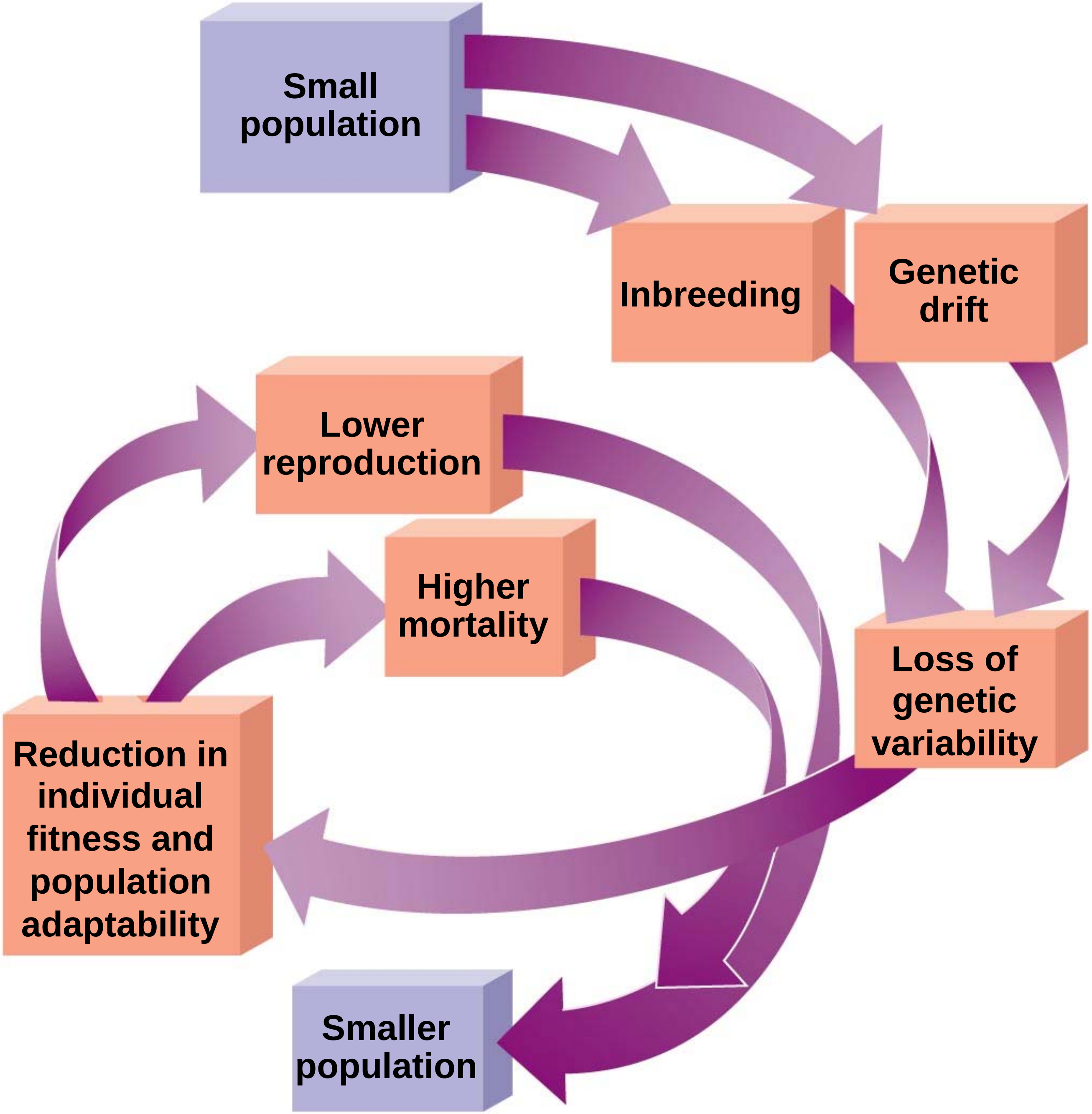
Small-Population Approach

- The small-population approach studies processes that can make small populations become extinct

The Extinction Vortex

- A small population is prone to positive-feedback loops that draw it down an **extinction vortex**
- The key factor driving the extinction vortex is loss of the genetic variation necessary to enable evolutionary responses to environmental change

Fig. 56-10



Small population
Inbreeding
Genetic drift
Lower reproduction
Higher mortality
Loss of genetic variability
Reduction in individual fitness and population adaptability
Smaller population

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

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

Fig. 56-11

RESULTS

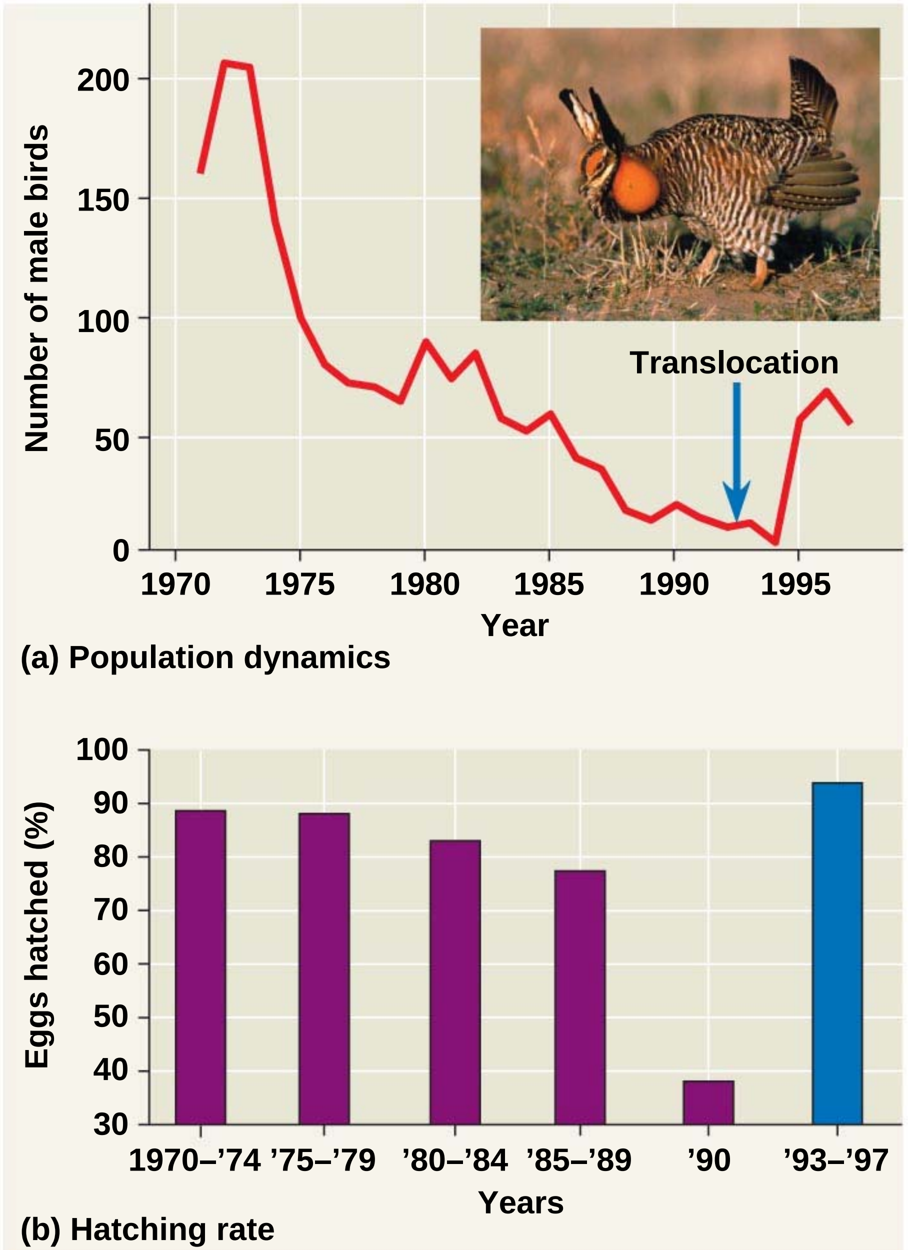
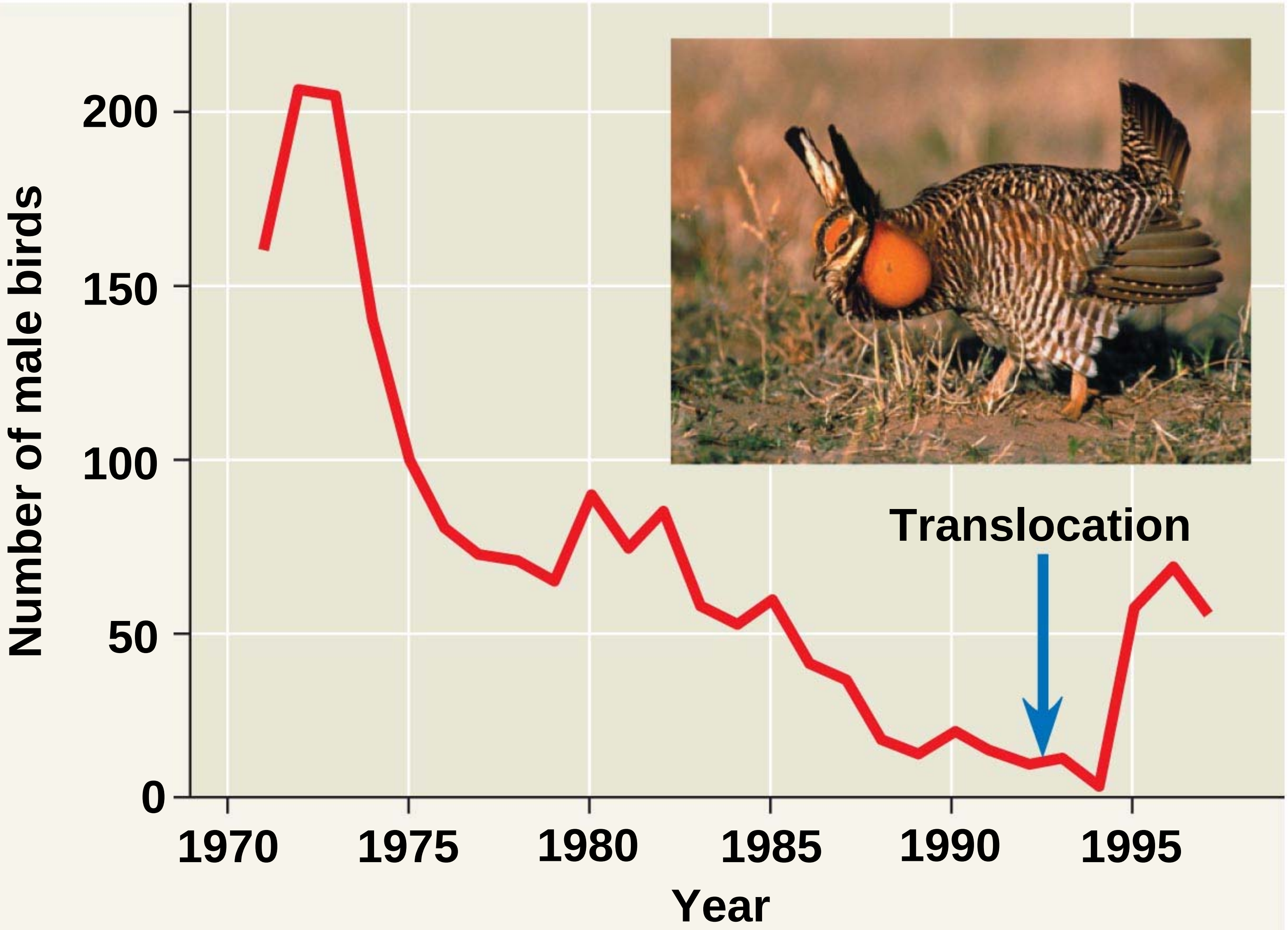


Fig. 56-11a

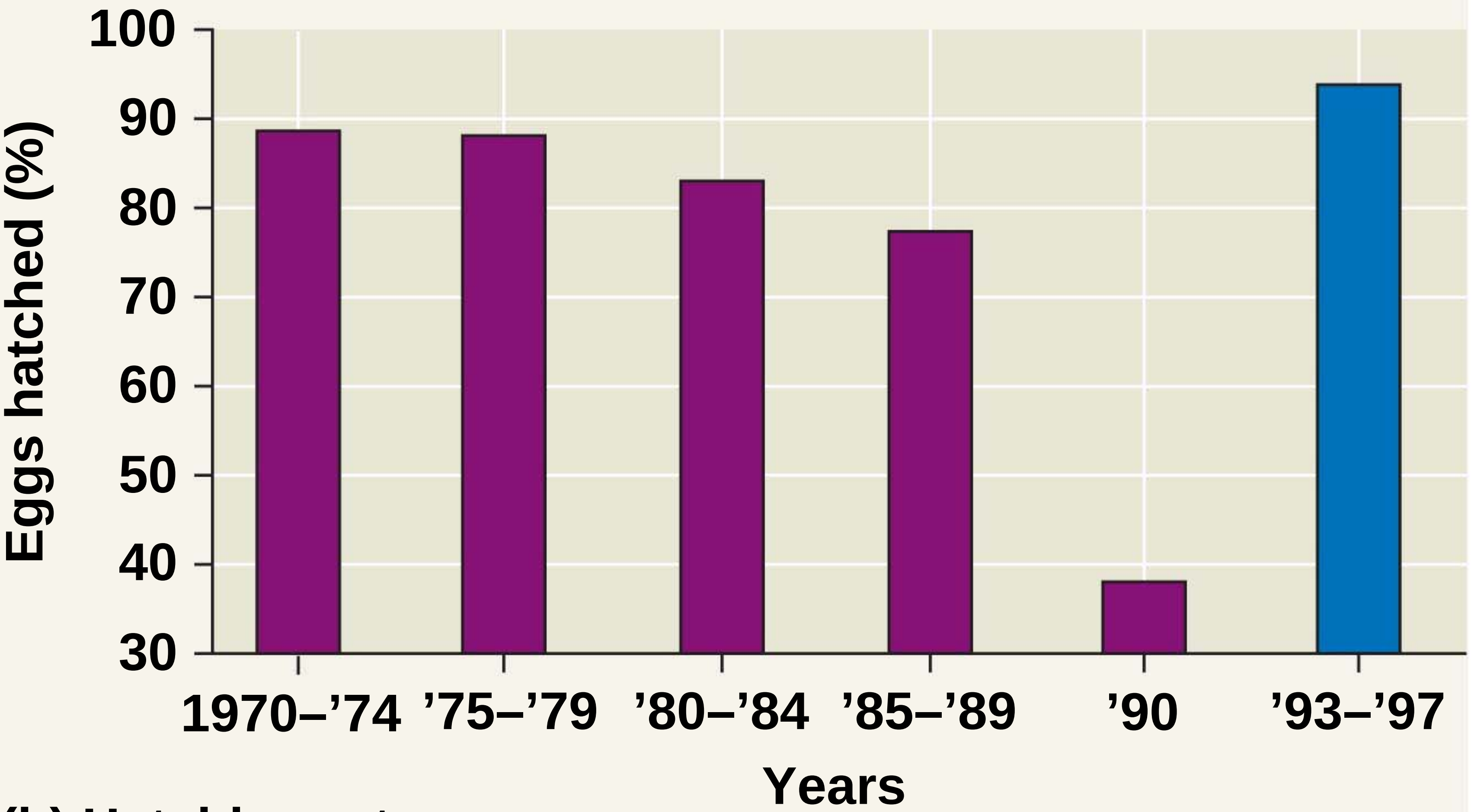
RESULTS



(a) Population dynamics

Fig. 56-11b

RESULTS



(b) Hatching rate

Minimum Viable Population Size

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

Effective Population Size

- A meaningful estimate of MVP requires determining the **effective population size**, which is based on the population's breeding potential

- Effective population size N_e is estimated by:

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

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

Case Study: *Analysis of Grizzly Bear Populations*

- One of the first population viability analyses was conducted as part of a long-term study of grizzly bears in Yellowstone National Park
- This grizzly population is about 400, but the N_e is about 100
- The Yellowstone grizzly population has low genetic variability compared with other grizzly populations

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

Fig. 56-12

Declining-Population Approach

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

Steps for Analysis and Intervention

- The declining-population approach involves several steps:
  - Confirm that the population is in decline
  - Study the species' natural history
  - Develop hypotheses for all possible causes of decline
  - Test the hypotheses in order of likeliness
  - Apply the results of the diagnosis to manage for recovery

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

- Red-cockaded woodpeckers require living trees in mature pine forests
- They have a complex social structure where one breeding pair has up to four “helper” individuals
- This species had been forced into decline by habitat destruction

Fig. 56-13

(a) Forests with low undergrowth

(b) Forests with high, dense undergrowth

Fig. 56-13a

(a) Forests with low undergrowth

Fig. 56-13b

(b) Forests with high, dense undergrowth

Fig. 56-13c

Red-cockaded woodpecker

- In a study where breeding cavities were constructed, new breeding groups formed only in these sites
- Based on this experiment, a combination of habitat maintenance and excavation of breeding cavities enabled this endangered species to rebound

Weighing Conflicting Demands

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

Concept 56.3: Landscape and regional conservation aim to sustain entire biotas

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

Landscape Structure and Biodiversity

- The structure of a landscape can strongly influence biodiversity

Fragmentation and Edges

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

Fig. 56-14

(a) Natural edges

(b) Edges created by human activity

Fig. 56-14a

(a) Natural edges

Fig. 56-14b

(b) Edges created by human activity

- The Biological Dynamics of Forest Fragments Project in the Amazon examines the effects of fragmentation on biodiversity
- Landscapes dominated by fragmented habitats support fewer species due to a loss of species adapted to habitat interiors

Fig. 56-15

Corridors That Connect Habitat Fragments

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

Fig. 56-16

Establishing Protected Areas

- Conservation biologists apply understanding of ecological dynamics in establishing protected areas to slow the loss of biodiversity
- Much of their focus has been on hot spots of biological diversity

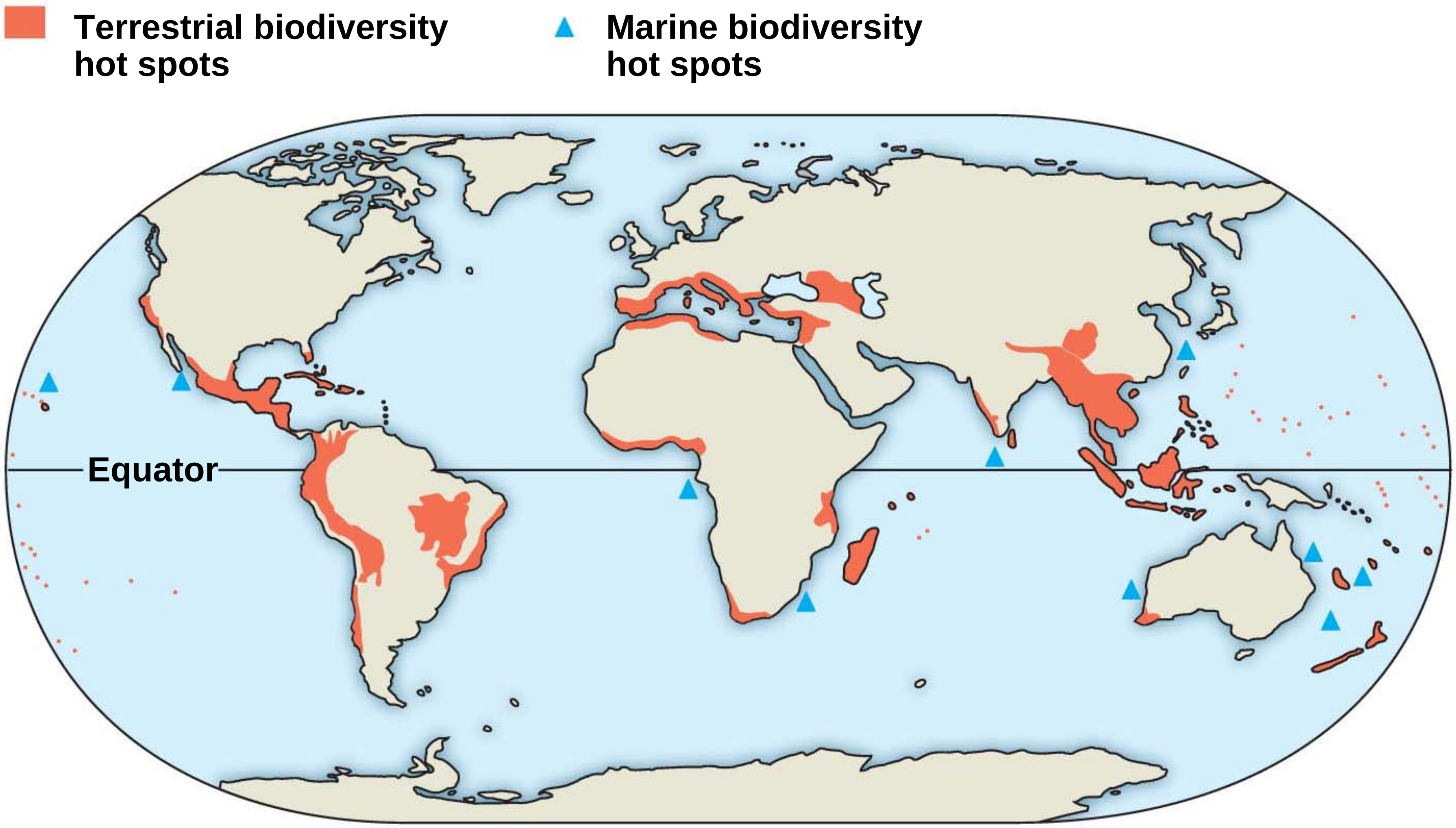
Finding Biodiversity Hot Spots

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

PLAY

Video: Coral Reef

Fig. 56-17

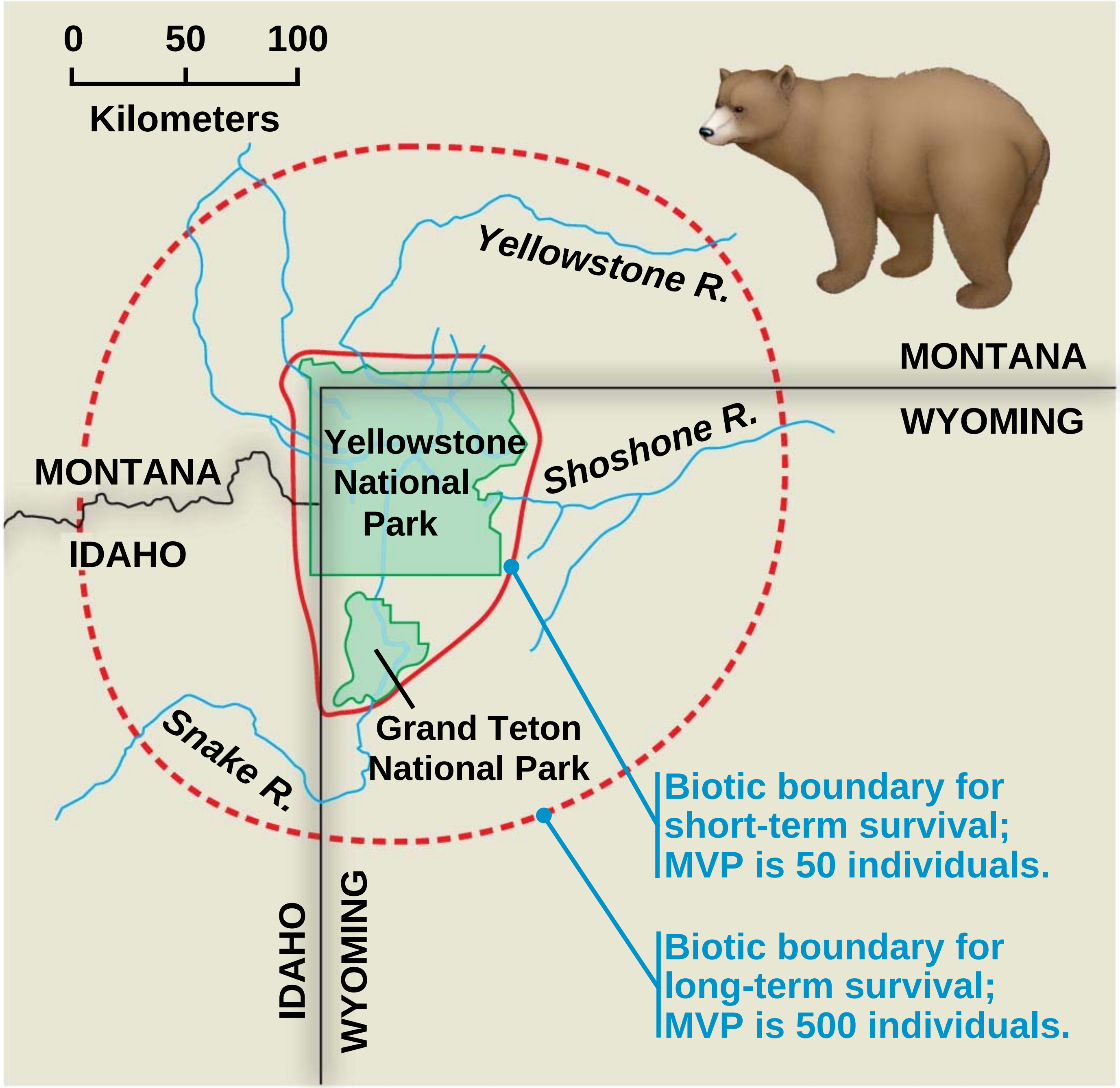

Terrestrial biodiversity hot spots
Marine biodiversity hot spots
Equator

Philosophy of Nature Reserves

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

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

Fig. 56-18


0
50
100
Kilometers
Yellowstone R.
MONTANA
WYOMING
Shoshone R.
MONTANA
IDAHO
Yellowstone National Park
Grand Teton National Park
Snake R.
IDAHO
WYOMING
Biotic boundary for short-term survival; MVP is 50 individuals.
Biotic boundary for long-term survival; MVP is 500 individuals.

Zoned Reserves

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

Fig. 56-19

(a) Zoned reserves in Costa Rica

(b) Schoolchildren in one of Costa Rica's reserves

Fig. 56-19a

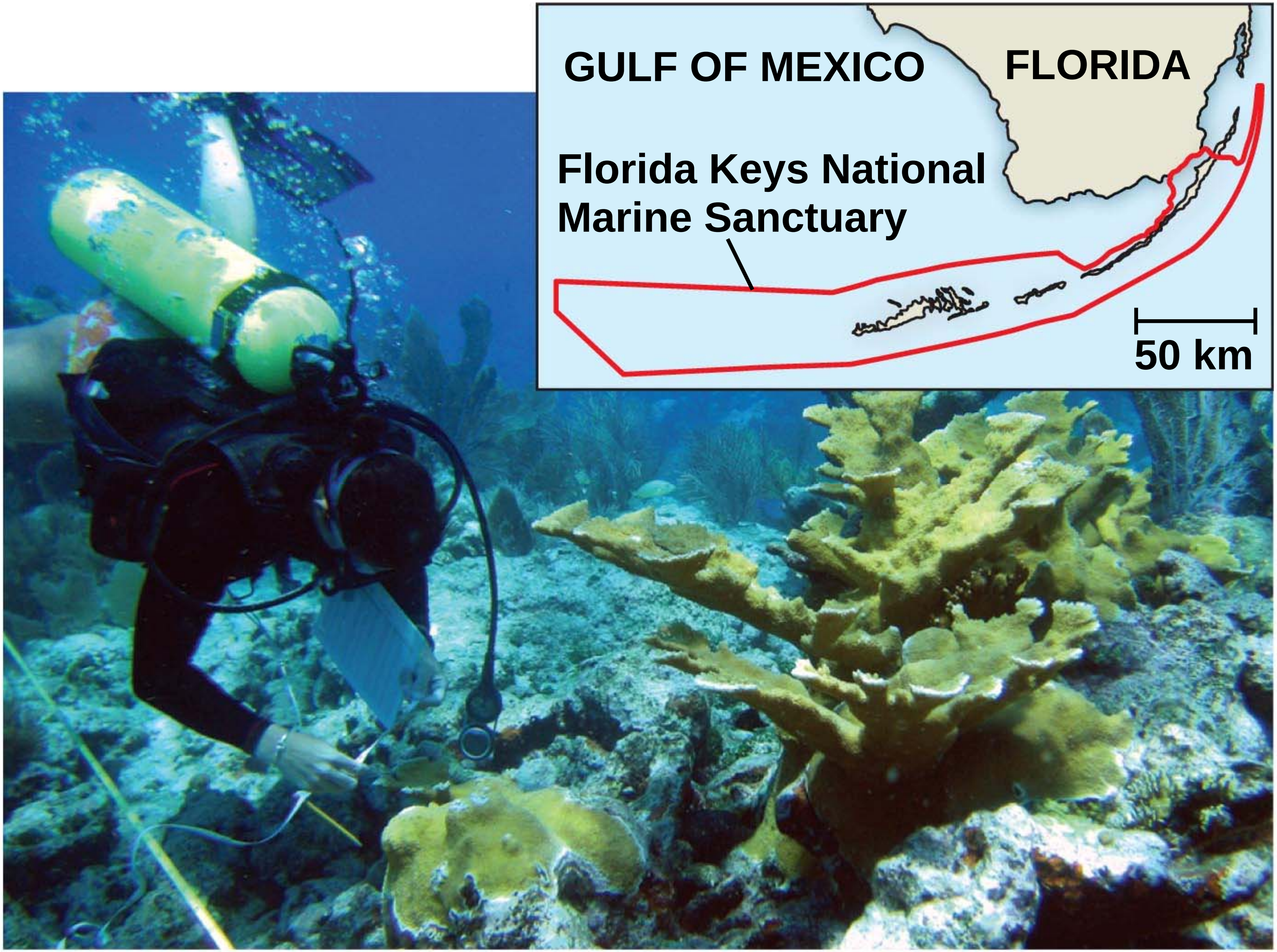
(a) Zoned reserves in Costa Rica

Fig. 56-19b

(b) Schoolchildren in one of Costa Rica's reserves

- Some zoned reserves in the Fiji islands are closed to fishing, which actually improves fishing success in nearby areas
- The United States has adopted a similar zoned reserve system with the Florida Keys National Marine Sanctuary

Fig. 56-20


GULF OF MEXICO
FLORIDA
Florida Keys National Marine Sanctuary
50 km

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

- Given enough time, biological communities can recover from many types of disturbances
- Restoration ecology seeks to initiate or speed up the recovery of degraded ecosystems
- A basic assumption of restoration ecology is that most environmental damage is reversible
- Two key strategies are bioremediation and augmentation of ecosystem processes

Fig. 56-21

(a) In 1991, before restoration

(b) In 2000, near the completion of restoration

Fig. 56-21a

(a) In 1991, before restoration

Fig. 56-21b

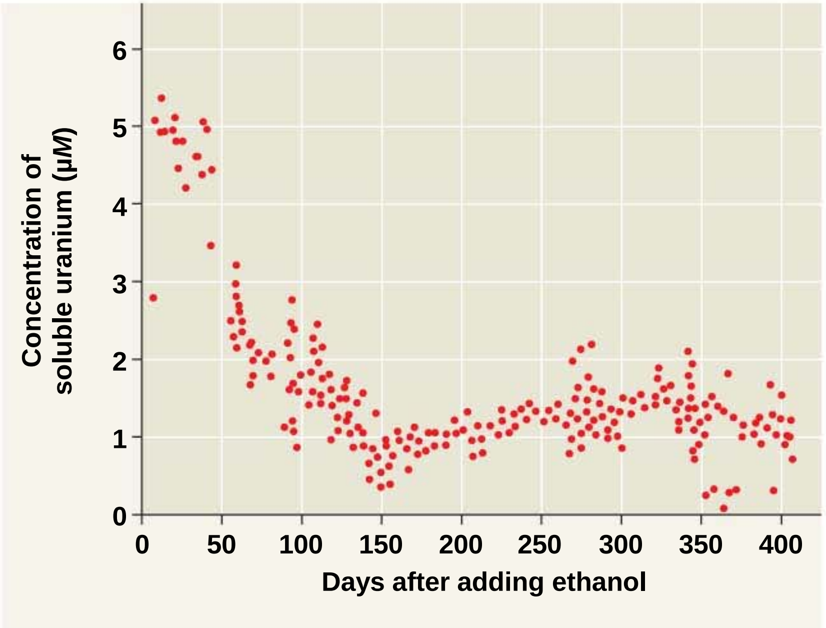
(b) In 2000, near the completion of restoration

Bioremediation

- **Bioremediation** is the use of living organisms to detoxify ecosystems
- The organisms most often used are prokaryotes, fungi, or plants
- These organisms can take up, and sometimes metabolize, toxic molecules

Fig. 56-22

(a) Unlined pits filled with wastes containing uranium

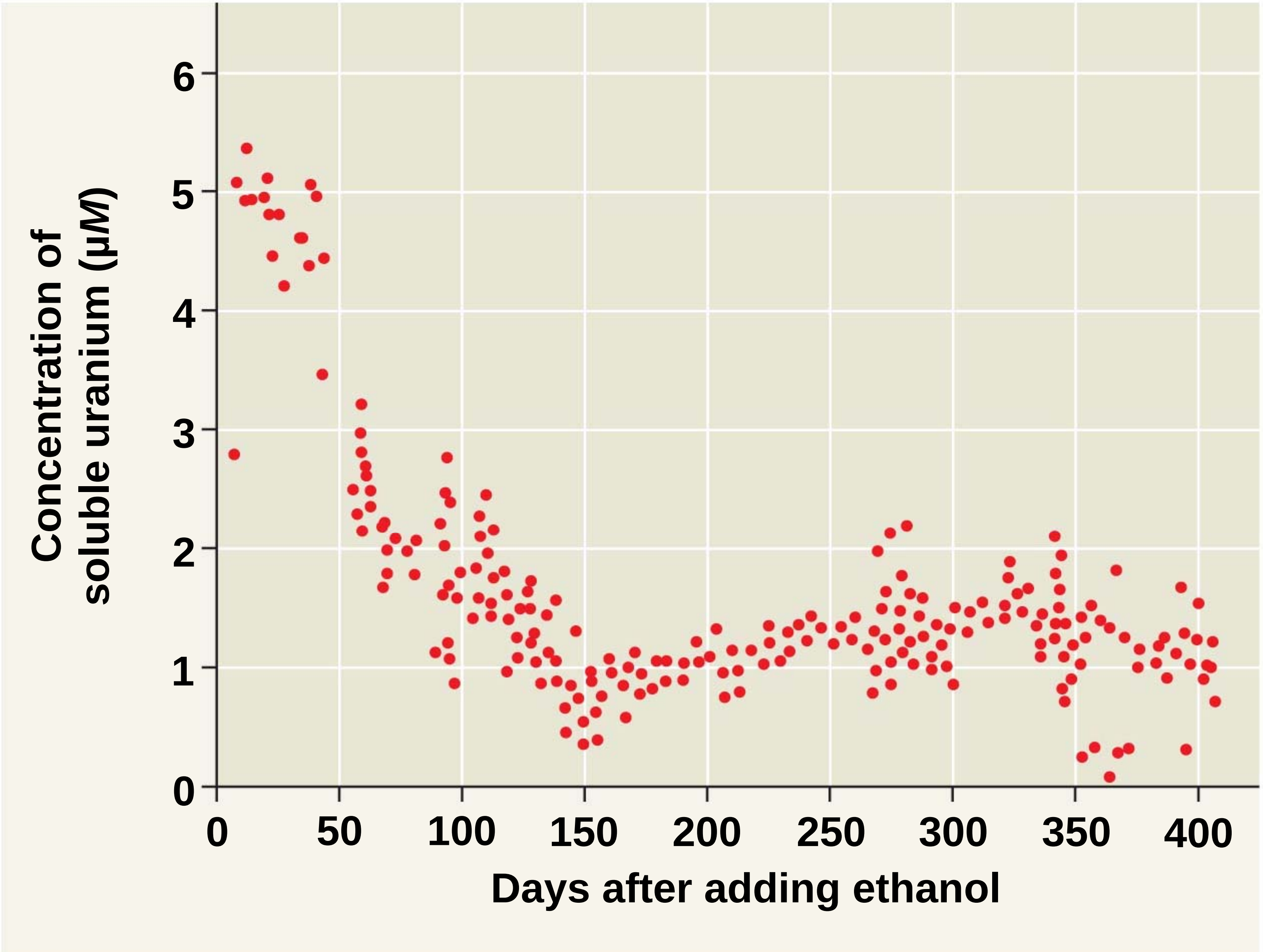


(b) Uranium in groundwater

Fig. 56-22a

(a) Unlined pits filled with wastes containing uranium

Fig. 56-22b



(b) Uranium in groundwater

Biological Augmentation

- **Biological augmentation** uses organisms to add essential materials to a degraded ecosystem
- For example, nitrogen-fixing plants can increase the available nitrogen in soil

Exploring Restoration

- The newness and complexity of restoration ecology require that ecologists consider alternative solutions and adjust approaches based on experience

Fig. 56-23a

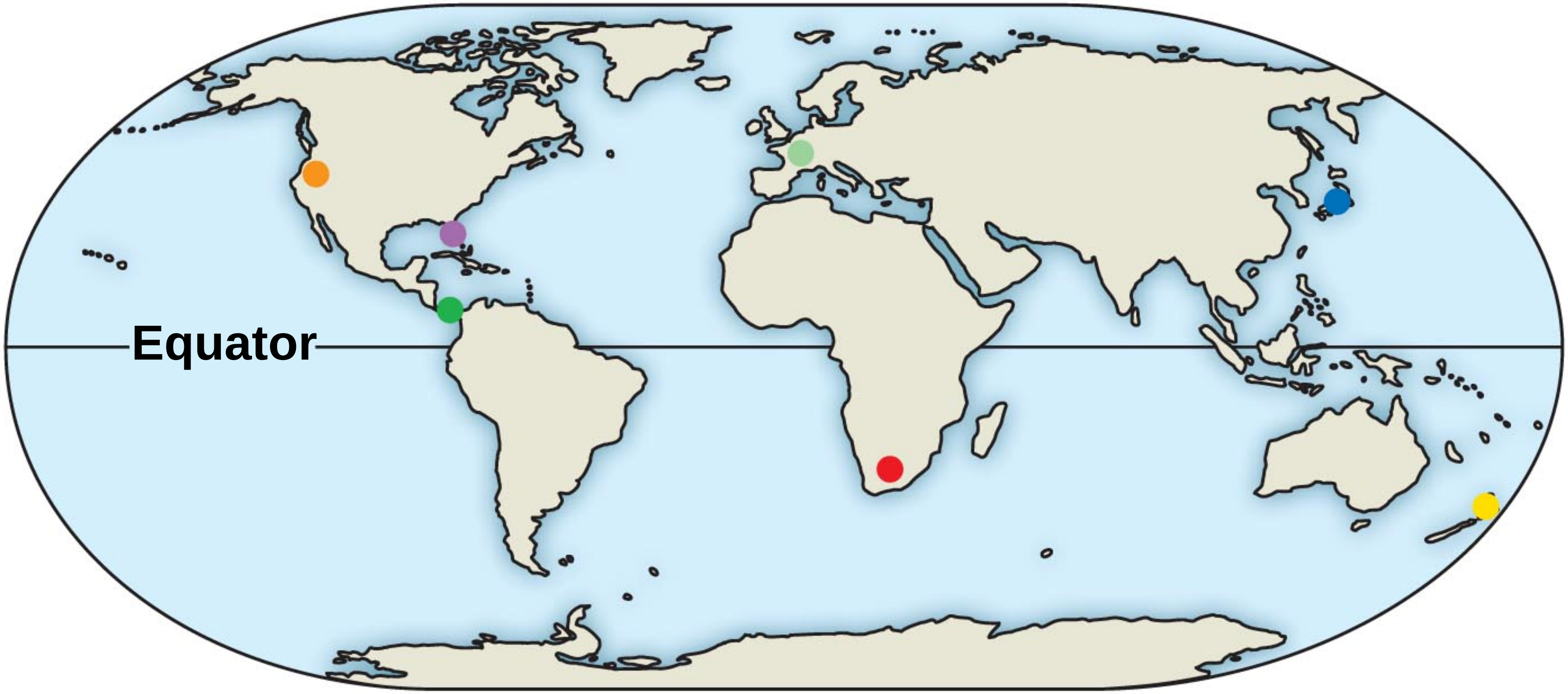


Fig. 56-23b

Truckee River, Nevada

Fig. 56-23c

Kissimmee River, Florida

Fig. 56-23d

Tropical dry forest, Costa Rica

Fig. 56-23e

Rhine River, Europe

Fig. 56-23f

● **Succulent Karoo, South Africa**

Fig. 56-23g

Coastal Japan

Fig. 56-23h

Maungatautari, New Zealand

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

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

Sustainable Biosphere Initiative

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

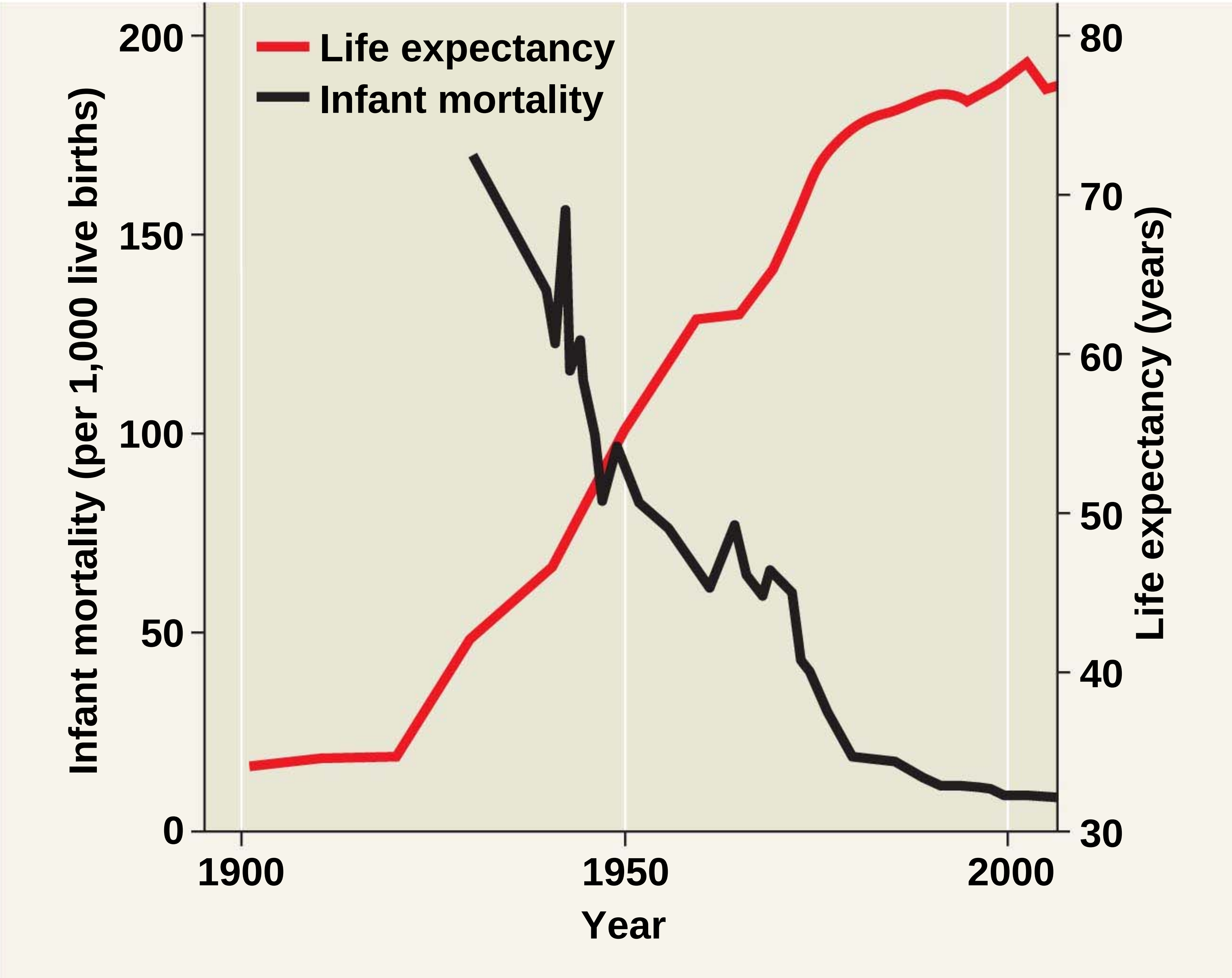
- Sustainable development requires connections between life sciences, social sciences, economics, and humanities

Case Study: Sustainable Development in Costa Rica

- Costa Rica's conservation of tropical biodiversity involves partnerships between the government, other organizations, and private citizens

- Human living conditions (infant mortality, life expectancy, literacy rate) in Costa Rica have improved along with ecological conservation

Fig. 56-24

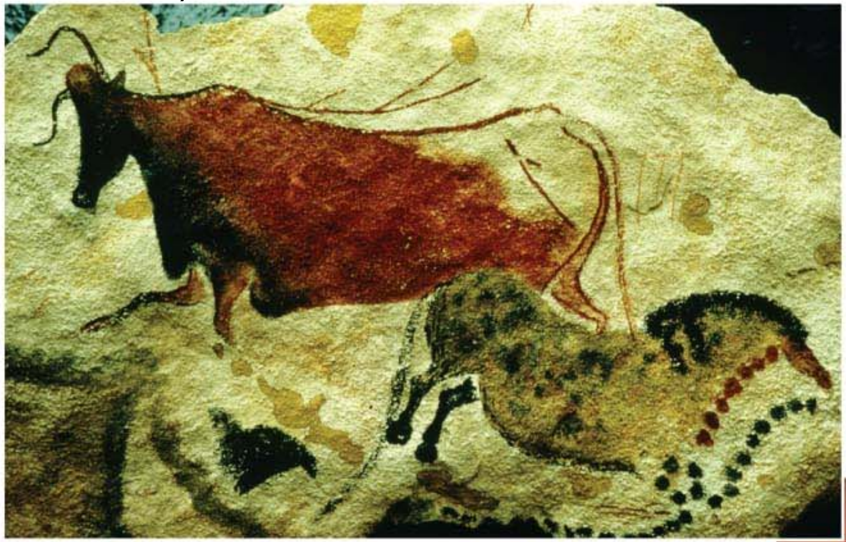

Life expectancy
Infant mortality
Infant mortality (per 1,000 live births)
200
150
100
50
0
Life expectancy (years)
80
70
60
50
40
30
1900
1950
2000
Year

The Future of the Biosphere

- Our lives differ greatly from early humans who hunted and gathered and painted on cave walls

Fig. 56-25

(a) Detail of animals in a 36,000-year-old cave painting, Lascaux, France



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

(c) Biologist Carlos Rivera Gonzales examining a tiny tree frog in Peru

Fig. 56-25a

(a) Detail of animals in a 36,000-year-old cave painting, Lascaux, France

Fig. 56-25b

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

Fig. 56-25c

(c) Biologist Carlos Rivera Gonzales examining a tiny tree frog in Peru

- Our behavior reflects remnants of our ancestral attachment to nature and the diversity of life—the concept of *biophilia*
- Our sense of connection to nature may motivate realignment of our environmental priorities

Fig. 56-UN1

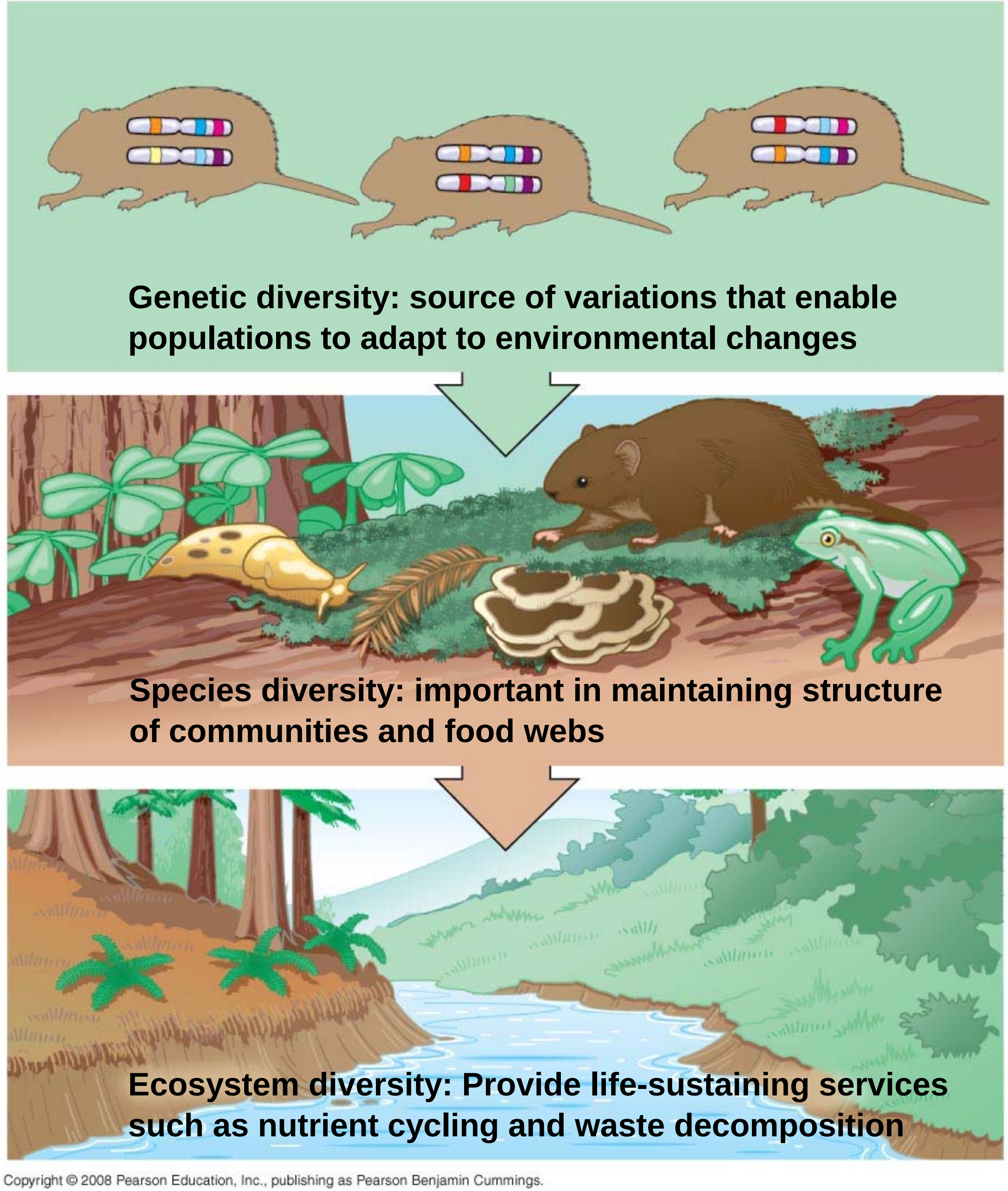
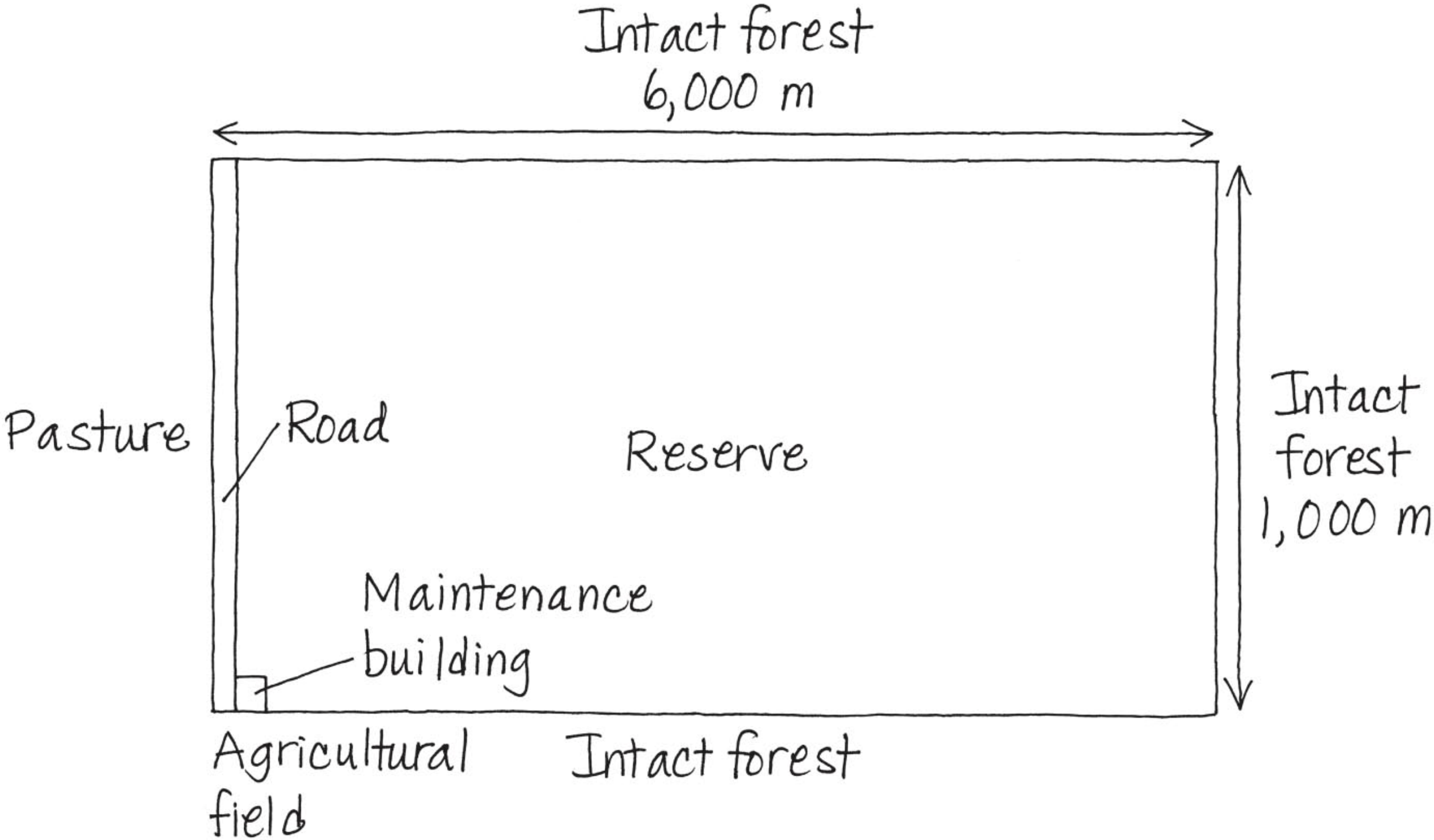

Genetic diversity: source of variations that enable populations to adapt to environmental changes
Species diversity: important in maintaining structure of communities and food webs
Ecosystem diversity: Provide life-sustaining services such as nutrient cycling and waste decomposition

Fig. 56-UN2



Intact forest
6,000 m
Pasture
Road
Reserve
Intact
forest
1,000 m
Maintenance
building
Agricultural
field
Intact forest

You should now be able to:

1. Distinguish between conservation biology and restoration biology
2. List the three major threats to biodiversity and give an example of each
3. Define and compare the small-population approach and the declining-population approach
4. Distinguish between the total population size and the effective population size

5. Describe the conflicting demands that may accompany species conservation
6. Define biodiversity hot spots and explain why they are important
7. Define zoned reserves and explain why they are important
8. Explain the importance of bioremediation and biological augmentation of ecosystem processes in restoration efforts

9. Describe the concept of sustainable development

10. Explain the goals of the Sustainable Biosphere Initiative