# Contents

# CHAPTER 1 The Web of Life 2

Deformity and Decline in Amphibian Populations: A Case Study 2

### **Introduction 3**

CONCEPT 1.1 Events in the natural world are interconnected. 3Connections in Nature 3

CONCEPT 1.2 Ecology is the scientific study of interactions between organisms and their environment. 8What Is Ecology? 8

**CONCEPT 1.3** Ecologists evaluate competing hypotheses about natural systems with observations, experiments, and models. 13

**Answering Ecological Questions 13** 



ECOLOGICAL TOOLKIT 1.1 Designing Ecological Experiments 15

ANALYZING DATA 1.1 Are Introduced Predators a Cause of Amphibian Decline? 17

A CASE STUDY REVISITED Deformity and Decline in Amphibian Populations 18

Mission Impossible? 18



Unit 1 Organisms and Their Environment 21

## CHAPTER 2 The Physical Environment 22

#### Climate Variation and Salmon Abundance: A Case Study 22

# **Introduction 23**

**CONCEPT 2.1** Climate is the most fundamental component of the physical environment. 23 **Climate 23** 

**CONCEPT 2.2** Winds and ocean currents result from differences in solar radiation across Earth's surface. 26

**Atmospheric and Oceanic Circulation 26** 

**CONCEPT 2.3** Large-scale atmospheric and oceanic circulation patterns establish global patterns of temperature and precipitation. 31

#### **Global Climate Patterns 31**

**CONCEPT 2.4** Regional climates reflect the influence of oceans and continents, mountains, and vegetation. 34

#### **Regional Climate Influences 34**

ANALYZING DATA 2.1 How Do Changes in Vegetation Cover Influence Climate? 37

**CONCEPT 2.5** Seasonal and long-term climate variation are associated with changes in Earth's position relative to the sun. 38

**Climate Variation over Time 38** 

**CONCEPT 2.6** Salinity, acidity, and oxygen

concentrations are major determinants of the chemical environment. 44

**The Chemical Environment 44** 

A CASE STUDY REVISITED Climate Variation and Salmon Abundance 46

CONNECTIONS IN NATURE Climate Variation and Ecology 47

# CHAPTER 3 The Biosphere 50

# The American Serengeti—Twelve Centuries of Change in the Great Plains: A Case Study 50

#### **Introduction 51**

**CONCEPT 3.1** Terrestrial biomes are characterized by the growth forms of the dominant vegetation. 51

# **Terrestrial Biomes 51**

ECOLOGICAL TOOLKIT 3.1 Climate Diagrams 54

CLIMATE CHANGE CONNECTION Tropical Forests and Greenhouse Gases 57

ANALYZING DATA 3.1 How Will Climate Change Affect the Grasslands Biome? 62

**CONCEPT 3.2** Biological zones in freshwater ecosystems are associated with the velocity, depth, temperature, clarity, and chemistry of the water. 71

#### **Freshwater Biological Zones 71**

**CONCEPT 3.3** Marine biological zones are determined by ocean depth, light availability, and the stability of the bottom substrate. 73

#### Marine Biological Zones 73

A CASE STUDY REVISITED The American Serengeti— Twelve Centuries of Change in the Great Plains 79

CONNECTIONS IN NATURE Long-Term Ecological Research 80

# CHAPTER 4 Coping with Environmental Variation: Temperature and Water 84

# Frozen Frogs: A Case Study 84

#### **Introduction 85**

**CONCEPT 4.1** Each species has a range of environmental tolerances that determines its potential geographic distribution. 85

**Responses to Environmental Variation 85** 

**CONCEPT 4.2** The temperature of an organism is determined by exchanges of energy with the external environment. 88

#### Variation in Temperature 88

ANALYZING DATA 4.1 How Does Fur Thickness Influence Metabolic Activity in Endotherms? 97

**CONCEPT 4.3** The water balance of an organism is determined by exchanges of water and solutes with the external environment. 98

#### Variation in Water Availability 98

A CASE STUDY REVISITED Frozen Frogs 105

CONNECTIONS IN NATURE
Desiccation Tolerance, Body Size, and Rarity 106

# CHAPTER 5 Coping with Environmental Variation: Energy 109

# Toolmaking Crows: A Case Study 109

#### Introduction 110

**CONCEPT 5.1** Organisms obtain energy from sunlight, from inorganic chemical compounds, or through the consumption of organic compounds. 110

#### Sources of Energy 110

**CONCEPT 5.2** Radiant and chemical energy captured by autotrophs is converted into stored energy in carbon–carbon bonds. 112

#### Autotrophy 112

ANALYZING DATA 5.1 How Does Acclimatization Affect Plant Energy Balance? 116

**CONCEPT 5.3** Environmental constraints have resulted in the evolution of biochemical pathways that improve the efficiency of photosynthesis. 117

#### Photosynthetic Pathways 117

**CONCEPT 5.4** Heterotrophs have adaptations for acquiring and assimilating energy efficiently from a variety of organic sources. 123

#### Heterotrophy 123

ECOLOGICAL TOOLKIT 5.1 Stable Isotopes 124

#### A CASE STUDY REVISITED Toolmaking Crows 129

CONNECTIONS IN NATURE

Tool Use: Adaptation or Learned Behavior? 130



# Unit 2 Evolutionary Ecology 135

# CHAPTER 6 Evolution and Ecology 136

# Trophy Hunting and Inadvertent Evolution: A Case Study 136

#### Introduction 137

**CONCEPT 6.1** Evolution can be viewed as genetic change over time or as a process of descent with modification. 137

What Is Evolution? 137

**CONCEPT 6.2** Natural selection, genetic drift, and gene flow can cause allele frequencies in a population to change over time. 140

# Mechanisms of Evolution 140

**CONCEPT 6.3** Natural selection is the only evolutionary mechanism that consistently causes adaptive evolution. 144

#### Adaptive Evolution 144

**CLIMATE CHANGE CONNECTION** Evolutionary Responses to Climate Change 146

**CONCEPT 6.4** Long-term patterns of evolution are shaped by large-scale processes such as speciation, mass extinction, and adaptive radiation. 148 **The Evolutionary History of Life 148** 

**CONCEPT 6.5** Ecological interactions and evolution exert a profound influence on one another. 153

Joint Effects of Ecology and Evolution 153

A CASE STUDY REVISITED Trophy Hunting and Inadvertent Evolution 155

CONNECTIONS IN NATURE The Human Impact on Evolution 156

ANALYZING DATA 6.1 Does Predation by Birds Cause Evolution in Moth Populations? 157

# CHAPTER 7 Life History 160

Nemo Grows Up: A Case Study 160

# **Introduction 161**

**CONCEPT 7.1** Life history patterns vary within and among species. 161

# Life History Diversity 161



CLIMATE CHANGE CONNECTION Climate Change and the Timing of Seasonal Activities 164 **CONCEPT 7.2** Reproductive patterns can be classified along several continua. 169

# Life History Continua 169

CONCEPT 7.3 There are trade-offs between life history traits. 172Trade-Offs 172

CONCEPT 7.4 Organisms face different selection pressures at different life cycle stages. 175Life Cycle Evolution 175

# ANALYZING DATA 7.1

Is There a Trade-Off between Current and Delayed Reproduction in the Collared Flycatcher? 175

A CASE STUDY REVISITED Nemo Grows Up 178

CONNECTIONS IN NATURE Territoriality, Competition, and Life History 179

# CHAPTER 8 Behavioral Ecology 182

# Baby Killers: A Case Study 182

#### Introduction 183

**CONCEPT 8.1** An evolutionary approach to the study of behavior leads to testable predictions. 183

# An Evolutionary Approach to Behavior 183

**CONCEPT 8.2** Animals make behavioral choices that enhance their energy gain and reduce their risk of becoming prey. 186

#### **Foraging Behavior 186**

**CONCEPT 8.3** Mating behaviors reflect the costs and benefits of parental investment and mate defense. 191

# Mating Behavior 191

**CONCEPT 8.4** There are advantages and disadvantages to living in groups. 196

# Living in Groups 196

ANALYZING DATA 8.1 Does the Dilution Effect Protect Individual Ocean Skaters from Fish Predators? 197

#### A CASE STUDY REVISITED Baby Killers 199

#### CONNECTIONS IN NATURE



Behavioral Responses to Predators Have Broad Ecological Effects 200



# Unit 3 **Populations 203**

# CHAPTER 9 Population Distribution and Abundance 204

# From Kelp Forest to Urchin Barren: A Case Study 204

# Introduction 205

**CONCEPT 9.1** Populations are dynamic entities that vary in size over time and space. 205

### **Populations 205**

**CONCEPT 9.2** The distributions and abundances of organisms are limited by habitat suitability, historical factors, and dispersal. 209

**Distribution and Abundance 209** 

#### ANALYZING DATA 9.1 Have Introduced Grasses Altered the Occurrence of Fires in Hawaiian Dry Forests? 211

**CONCEPT 9.3** Many species have a patchy distribution of populations across their geographic range. 213

#### **Geographic Range 213**

**CONCEPT 9.4** The dispersion of individuals within a population depends on the location of essential resources, competition, dispersal, and behavioral interactions. 215

# **Dispersion within Populations 215**

# **CONCEPT 9.5** Population abundances and

distributions can be estimated with area-based counts, distance methods, mark-recapture studies, and niche models. 216

# **Estimating Abundances and Distributions 216**

ECOLOGICAL TOOLKIT 9.1 Estimating Abundance 218

A CASE STUDY REVISITED From Kelp Forest to Urchin Barren 221

# **CONNECTIONS IN NATURE**

From Urchins to Ecosystems 222

#### **CLIMATE CHANGE CONNECTION**

Effects of Climate Change on the Geographic Distributions of Species 223

# CHAPTER 10 Population Growth and **Regulation 226**

# Human Population Growth: A Case Study 226

# Introduction 227

**CONCEPT 10.1** Life tables show how survival and reproductive rates vary with age, size, or life cycle stage. 228

# Life Tables 228

**CONCEPT 10.2** Life table data can be used to project the future age structure, size, and growth rate of a population. 231

#### Age Structure 231



**CLIMATE CHANGE CONNECTION** 



Effects of Climate Change on Tree Mortality Rates 234 ECOLOGICAL TOOLKIT 10.1

**Estimating Population Growth Rates in a Threatened** Species 235

**CONCEPT 10.3** Populations can grow exponentially when conditions are favorable, but exponential growth cannot continue indefinitely. 236

#### **Exponential Growth 236**

- ANALYZING DATA 10.1 How Has the Growth of the Human Population Changed over Time? 238
- **CONCEPT 10.4** Population size can be determined by density-dependent and density-independent factors. 240

# **Effects of Density 240**

**CONCEPT 10.5** The logistic equation incorporates limits to growth and shows how a population may stabilize at a maximum size, the carrying capacity. 242 Logistic Growth 242

A CASE STUDY REVISITED Human Population Growth 244

**CONNECTIONS IN NATURE** Your Ecological Footprint 245

# CHAPTER 11 Population Dynamics 249

#### A Sea in Trouble: A Case Study 249

#### **Introduction 250**

**CONCEPT 11.1** Population growth patterns include exponential growth, logistic growth, fluctuations, and regular cycles. 251

#### Patterns of Population Growth 251

CLIMATE CHANGE CONNECTION Collapsing Population Cycles and Climate Change 254

**CONCEPT 11.2** Delayed density dependence can cause populations to fluctuate in size. 254

# Unit 4 Species Interactions 271

# CHAPTER 12 Predation 272

# Snowshoe Hare Cycles: A Case Study 272 Introduction 273

**CONCEPT 12.1** Most carnivores have broad diets, whereas a majority of herbivores have relatively narrow diets. 274

#### **Carnivore and Herbivore Dietary Preferences 274**

**CONCEPT 12.2** Predation results in a wide range of capture and avoidance mechanisms. 276

#### **Mechanisms Important to Predation 276**

**CONCEPT 12.3** Predator populations can cycle with their prey populations. 281

#### **Predator-Prey Population Cycles 281**

ANALYZING DATA 12.1 Do Different Herbivore Species Select for Different Plant Genotypes? 282

**CONCEPT 12.4** Predation can affect prey distribution and abundance, in some cases causing a shift from one community type to another. 286

#### **Effects of Predation on Communities 286**

A CASE STUDY REVISITED Snowshoe Hare Cycles 290

#### **CONNECTIONS IN NATURE**



From Fear to Hormones to Population Dynamics 291

# CHAPTER 13 Parasitism 294

**Delayed Density Dependence 254** 

small populations. 257

ANALYZING DATA 11.1

**Metapopulations 263** 

**Population Extinction 257** 

**CONCEPT 11.3** The risk of extinction increases greatly in

How Does Variation in  $\lambda$  Affect Population Growth? 258

**CONCEPT 11.4** In metapopulations, sets of spatially

From Bottom to Top, and Back Again 266

A CASE STUDY REVISITED A Sea in Trouble 265

**CONNECTIONS IN NATURE** 

isolated populations are linked by dispersal. 263

# Enslaver Parasites: A Case Study 294

#### Introduction 295

**CONCEPT 13.1** Parasites typically feed on only one or a few host species, but host species have multiple parasite species. 296

#### Parasite Natural History 296

**CONCEPT 13.2** Hosts have mechanisms for defending themselves against parasites, and parasites have mechanisms for overcoming host defenses. 298

#### Defense and Counterdefenses 298

ANALYZING DATA 13.1 Will a Defensive Symbiont Increase in Frequency in a Host Population Subjected to Parasitism? 300

**CONCEPT 13.3** Host and parasite populations can evolve together, each in response to selection pressure imposed by the other. 302

#### Parasite-Host Coevolution 302

**CONCEPT 13.4** Hosts and parasites can have important effects on each other's population dynamics. 305

# Host-Parasite Population Dynamics 305

**CONCEPT 13.5** Parasites can alter the outcomes of species interactions, thereby causing communities to change. 309

Parasites Can Change Ecological Communities 309



Climate Change and Disease Spread 310

A CASE STUDY REVISITED Enslaver Parasites 313

**CONNECTIONS IN NATURE** From Chemicals to Evolution and Ecosystems 314

# CHAPTER 14 Competition 317

# Competition in Plants That Eat Animals: A Case Study 317

#### **Introduction 318**

**CONCEPT 14.1** Competition can be direct or indirect, vary in its intensity, and occur between similar or dissimilar species. 319

**General Features of Competition 319** 

CONCEPT 14.2 Competing species are more likely to coexist when they use resources in different ways. 322Competitive Coexistence 322

**CONCEPT 14.3** Competitive interactions can be modeled using the logistic equation. 325

The Lotka-Volterra Competition Model 325

- ANALYZING DATA 14.1 Will Competition with a Native Mosquito Species Prevent the Spread of an Introduced Mosquito? 329
- **CONCEPT 14.4** The outcome of competition can be altered by the physical environment, disturbance, and predation. 329

Altering the Outcome of Competition 329

A CASE STUDY REVISITED Competition in Plants That Eat Animals 332



# CHAPTER 15 ■ Mutualism and Commensalism 336

# The First Farmers: A Case Study 336 Introduction 337

**CONCEPT 15.1** In positive interactions, no species is harmed and the benefits are greater than the costs for at least one species. 337

#### **Positive Interactions 337**

**CONCEPT 15.2** Each partner in a mutualistic interaction acts in ways that serve its own ecological and evolutionary interests. 343

# **Characteristics of Mutualism 343**

ANALYZING DATA 15.1 Does a Mycorrhizal Fungus Transfer More Phosphorus to Plant Roots That Provide More Carbohydrates? 345

CONCEPT 15.3 Positive interactions affect the abundances and distributions of populations as well as the structure of ecological communities. 347
 Ecological Consequences of Positive Interactions 347

#### A CASE STUDY REVISITED The First Farmers 351

CONNECTIONS IN NATURE

I From Mandibles to Nutrient Cycling 351



Unit 5

**Communities 355** 

# CHAPTER 16 The Nature of Communities 356

# "Killer Algae!": A Case Study 356

#### Introduction 357

**CONCEPT 16.1** Communities are groups of interacting species that occur together at the same place and time. 357

### What Are Communities? 357

CONCEPT 16.2 Species diversity and species composition are important descriptors of community structure. 360Community Structure 360 ANALYZING DATA 16.1 What Are the Effects of Invasive Species on Species Diversity? 363

**CONCEPT 16.3** Communities can be characterized by complex networks of direct and indirect interactions that vary in strength and direction. 365 **Interactions of Multiple Species 365** 

ECOLOGICAL TOOLKIT 16.1 Measurements of Interaction Strength 369



CLIMATE CHANGE CONNECTION Context Dependence of Ocean Acidification 372

A CASE STUDY REVISITED "Killer Algae!" 373

CONNECTIONS IN NATURE



# CHAPTER 17 Change in **Communities 377**

# A Natural Experiment of Mountainous Proportions: A Case Study 377

### **Introduction 378**

**CONCEPT 17.1** Agents of change act on communities across all temporal and spatial scales. 379

# Agents of Change 379

**CONCEPT 17.2** Succession is the process of change in species composition over time as a result of abiotic and biotic agents of change. 381

# The Basics of Succession 381

**CONCEPT 17.3** Experimental work on succession shows its mechanisms to be diverse and contextdependent. 384

#### Mechanisms of Succession 384

#### ANALYZING DATA 17.1 What Kinds of Species Interactions Drive Succession in Mountain Forests? 391

**CONCEPT 17.4** Communities can follow different successional paths and display alternative states. 392 **Alternative Stable States 392** 

A CASE STUDY REVISITED A Natural Experiment of **Mountainous Proportions 394** 

CONNECTIONS IN NATURE Primary Succession and Mutualism 396

# CHAPTER 18 Biogeography 399

# The Largest Ecological Experiment on Earth: A Case Study 399

#### **Introduction 400**

**CONCEPT 18.1** Patterns of species diversity and distribution vary at global, regional, and local spatial scales. 401

# **Biogeography and Spatial Scale 401**

**CONCEPT 18.2** Global patterns of species diversity and composition are influenced by geographic area and isolation, evolutionary history, and global climate. 406

# **Global Biogeography 406**



CLIMATE CHANGE CONNECTION Latitudinal Gradients in Diversity under Climate Change 414

**CONCEPT 18.3** Regional differences in species diversity are influenced by area and distance, which determine the balance between immigration and extinction rates. 415

# **Regional Biogeography 415**

- ECOLOGICAL TOOLKIT 18.1 Species-Area Curves 416
- ANALYZING DATA 18.1 Do Species Invasions Influence Species-Area Curves? 417

A CASE STUDY REVISITED The Largest Ecological Experiment on Earth 420

CONNECTIONS IN NATURE Tropical Rainforest Diversity Benefits Humans 422

# CHAPTER 19 Species Diversity in **Communities 424**

# Can Species Diversity Suppress Human Diseases? A Case Study 424

# **Introduction 425**

**CONCEPT 19.1** Species diversity differs among communities as a consequence of regional species pools, abiotic conditions, and species interactions. 425

### **Community Membership 425**



CLIMATE CHANGE CONNECTION How Are Species Invasions Enhanced by Climate Change? 428

**CONCEPT 19.2** Resource partitioning is theorized to reduce competition and increase species diversity. 429 **Resource Partitioning 429** 

**CONCEPT 19.3** Processes such as disturbance, stress, predation, and positive interactions can mediate resource availability, thus promoting species diversity. 432

# **Resource Mediation and Species Diversity 432**

#### ANALYZING DATA 19.1 How Do Predation and Dispersal Interact to Influence Species Richness? 438

**CONCEPT 19.4** Many experiments show that species diversity affects community function. 440

#### The Consequences of Diversity 440

A CASE STUDY REVISITED Can Species Diversity Suppress Human Diseases? 442

#### **CONNECTIONS IN NATURE**

Managing Pathogens by Managing Biodiversity 443



# Unit 6 **Ecosystems 447**

# CHAPTER 20 Production 448

Life in the Deep Blue Sea, How Can It Be? A Case Study 448

#### **Introduction 449**

**CONCEPT 20.1** Energy in ecosystems originates with primary production by autotrophs. 450

#### **Primary Production 450**

- ECOLOGICAL TOOLKIT 20.1 **Remote Sensing** 454
- ANALYZING DATA 20.1 **Does Deforestation Influence Atmospheric** CO, Concentrations? 456
- **CONCEPT 20.2** Net primary production is constrained by both physical and biotic environmental factors. 457 **Environmental Controls on NPP 457**
- **CONCEPT 20.3** Global patterns of net primary production reflect climate constraints and biome types. 462

#### **Global Patterns of NPP 462**

**CONCEPT 20.4** Secondary production is generated through the consumption of organic matter by heterotrophs. 463

#### Secondary Production 463

A CASE STUDY REVISITED Life in the Deep Blue Sea, How Can It Be? 465

#### **CONNECTIONS IN NATURE 466**

**Energy-Driven Succession and Evolution in** Hydrothermal Vent Communities 466

# CHAPTER 21 Energy Flow and Food Webs 470

#### Toxins in Remote Places: A Case Study 470

#### **Introduction 471**

**CONCEPT 21.1** Trophic levels describe the feeding positions of groups of organisms in ecosystems. 471 Feeding Relationships 471

**CONCEPT 21.2** The amount of energy transferred from one trophic level to the next depends on food quality and on consumer abundance and physiology. 473

**Energy Flow between Trophic Levels 473** 

**CONCEPT 21.3** Changes in the abundances of organisms at one trophic level can influence energy flow at multiple trophic levels. 478

#### **Trophic Cascades** 478

ANALYZING DATA 21.1 Does the Identity of Organisms Influence Energy Flow between Trophic Levels? 482

**CONCEPT 21.4** Food webs are conceptual models of the trophic interactions of organisms in an ecosystem. 482 Food Webs 482

A CASE STUDY REVISITED Toxins in Remote Places 488



**Biological Transport of Pollutants 489** 

# CHAPTER 22 Nutrient Supply and Cycling 493

# A Fragile Crust: A Case Study 493

**Introduction 494** 

**CONCEPT 22.1** Nutrients enter ecosystems through the chemical breakdown of minerals in rocks or through fixation of atmospheric gases. 495

Nutrient Requirements and Sources 495

**CONCEPT 22.2** Chemical and biological transformations in ecosystems alter the chemical form and supply of nutrients. 499

**Nutrient Transformations** 499

ANALYZING DATA 22.1 Does Lignin Always Inhibit Decomposition? 501

**CONCEPT 22.3** Nutrients cycle repeatedly through the components of ecosystems. 502

#### Nutrient Cycles and Losses 502

- **ECOLOGICAL TOOLKIT 22.1** Instrumenting Catchments 506
- **CONCEPT 22.4** Freshwater and marine nutrient cycles occur in a moving medium and are linked to terrestrial ecosystems. 508

#### Nutrients in Aquatic Ecosystems 508

#### A CASE STUDY REVISITED A Fragile Crust 512

**CONNECTIONS IN NATURE** 

Nutrients, Disturbance, and Invasive Species 513



# Unit 7 Applied and Large-Scale Ecology 517

# CHAPTER 23 Conservation Biology 518

# Can Birds and Bombs Coexist? A Case Study 518 Introduction 519

**CONCEPT 23.1** Conservation biology is an integrative discipline that applies the principles of ecology to the protection of biodiversity. 519

#### **Conservation Biology 519**

**CONCEPT 23.2** Biodiversity is declining globally. 522 **Declining Biodiversity 522** 

**CONCEPT 23.3** Primary threats to biodiversity include habitat loss, invasive species, overexploitation, pollution, disease, and climate change. 526

#### **Threats to Biodiversity 526**

ANALYZING DATA 23.1 Do Nitric Oxide Emissions Differ Statistically between Plots with and without Kudzu? 529

CLIMATE CHANGE CONNECTION Impacts on Biodiversity 532

**CONCEPT 23.4** Conservation biologists use many tools and work at multiple scales to manage declining populations. 533

#### **Approaches to Conservation 533**

ECOLOGICAL TOOLKIT 23.1 Forensics in Conservation Biology 535

**CONCEPT 23.5** Prioritizing species helps maximize the biodiversity that can be protected with limited resources. 538

#### **Ranking Species for Protection 538**

A CASE STUDY REVISITED Can Birds and Bombs Coexist? 540

CONNECTIONS IN NATURE Some Burning Questions 541

# CHAPTER 24 Landscape Ecology and Ecosystem Management 544

# Wolves in the Yellowstone Landscape: A Case Study 544

#### Introduction 545

ECOLOGICAL TOOLKIT 24.1 Geographic Information Systems (GIS) 546 **CONCEPT 24.1** Landscape ecology examines spatial patterns and their relationship to ecological processes. 547

#### Landscape Ecology 547

**CONCEPT 24.2** Habitat loss and fragmentation decrease habitat area, isolate populations, and alter conditions at habitat edges. 552

#### Habitat Loss and Fragmentation 552

ANALYZING DATA 24.1 How Far Do Edge Effects Penetrate into Forest Fragments? 556

**CONCEPT 24.3** Biodiversity can best be sustained by large reserves connected across the landscape and buffered from areas of intense human use. 557

#### **Designing Nature Reserves 557**

**CONCEPT 24.4** Ecosystem management is a collaborative process with the maintenance of long-term ecological integrity as its core value. 561

#### Ecosystem Management 561

A CASE STUDY REVISITED Wolves in the Yellowstone Landscape 563

CONNECTIONS IN NATURE

Future Changes in the Yellowstone Landscape 564

# CHAPTER 25 Global Ecology 568

# **Dust Storms of Epic Proportions: A Case Study 568** Introduction 569

**CONCEPT 25.1** Elements move among geologic, atmospheric, oceanic, and biological pools at a global scale. 569

#### **Global Biogeochemical Cycles 569**

ANALYZING DATA 25.1 How Much Will Ocean pH Drop in the Twenty-First Century? 572

CONCEPT 25.2 Earth is warming because of anthropogenic emissions of greenhouse gases. 577Global Climate Change 577

**CONCEPT 25.3** Anthropogenic emissions of sulfur and nitrogen cause acid deposition, alter soil chemistry, and affect the health of ecosystems. 583

Acid and Nitrogen Deposition 583

**CONCEPT 25.4** Losses of ozone in the stratosphere and increases in ozone in the troposphere both pose risks to organisms. 588

# Atmospheric Ozone 588

A CASE STUDY REVISITED Dust Storms of Epic Proportions 590

CONNECTIONS IN NATURE

Dust as a Vector of Ecological Impacts 592

Appendix: Some Metric Measurements Used in Ecology AP-1 Answers AN-1 Glossary G-1 Illustration and Photo Credits C-1 Literature Cited LC-1 Index I-1