

4

Species Interactions and Community Ecology

Chapter Objectives

This chapter will help students:

- Compare and contrast the major types of species interactions
- Characterize feeding relationships and energy flow, using them to construct trophic levels and food webs
- Distinguish characteristics of a keystone species
- Characterize succession, community change, and the debate over the nature of communities
- Perceive and predict the potential impacts of invasive species in communities
- Explain the goals and the methods of restoration ecology
- Describe and illustrate the terrestrial biomes of the world

Lecture Outline

- I. **Central Case: Black and White, and Spread All Over: Zebra Mussels Invade the Great Lakes**
 - A. The pollution-fouled waters of Lake Erie and the other Great Lakes shared by Canada and the United States became gradually cleaner in the years following the Clean Water Act of 1970.
 - B. Then the zebra mussel, a native to western Asia and eastern Europe, arrived by accident in the ballast water of ships.
 - C. By 2010, they had colonized waters in 30 U.S. states.
 - D. The zebra mussels' larval stage is well adapted for long-distance dispersal, and it has encountered none of the predators, competitors, and parasites that evolved to limit its population growth in the Old World.

- E. Zebra mussels can clog up water intake pipes, damage boat engines, degrade docks, foul fishing gear, and sink buoys that ships use for navigation.
- F. Zebra mussels also have severe impacts on the ecological systems they invade. Among the most significant impacts, is their ability to take large quantities of food (**phytoplankton**) needed by native mollusks for food.
- G. Phytoplankton is the foundation of the Great Lakes food web, so its depletion is bad news for **zooplankton**, the tiny aquatic animals and protists that eat phytoplankton—and for the fish that eat both.
- H. By filter feeding, zebra mussels clear the water, allowing the community's nutrient balance to shift to the bottom, possibly benefitting species feeding there.
- I. Most recently, the zebra mussel is being displaced by the quagga mussel. Scientists do not yet understand the complex interactions driving the change. The quagga has a larger niche than any native mussels and even the zebra mussel.

II. Species Interactions

- A. **Competition** can occur when resources are limited.
 1. Competitive interactions can take place among members of the same species (**intraspecific competition**), or among members of two or more different species (**interspecific competition**).
 2. A competitive relationship is represented in Table 4.1 as a -/- interaction.
 3. **Competitive exclusion** occurs when one species excludes the other from resource use entirely.
 4. Competing species that live side-by-side at a certain ratio of population sizes may reach a stable equilibrium point—**species coexistence**.
 5. Coexisting species that use the same resources tend to minimize competition by using only a portion of the total array of resources—their niche, or ecological role in the community—that they are capable of using.
 - a. The full niche of a species is called its **fundamental niche**.
 - b. An individual that plays only part of its role because of competition or other species interactions is said to be displaying a **realized niche**.
 6. Over time, competing species may evolve to use slightly different resources or to use their shared resources in different ways; this is **resource partitioning**.
 - a. Because species limit their resource use, over time, **character displacement** may occur as they evolve physical characteristics that reflect their reliance on a particular portion of the resource.

- B. Several types of interactions are *exploitative*.
1. Exploitation occurs when one member of an interaction exploits another for its own gain.
 2. An exploitative interaction is represented in Table 4.1 as a +/- relationship.
 3. Predators kill and consume prey.
 - a. **Predation** is the process by which an individual of one species, a predator, hunts, captures, kills, and consumes an individual of another species, its *prey*.
 - b. Predation can sometimes drive population dynamics, causing cycles in population sizes.
 - c. Predation also has evolutionary ramifications: More adept predators will leave more and healthier offspring, leading to the evolution of adaptations that make them better hunters. The same selective pressure acts on prey species that evolve defenses against being eaten.
 4. Parasites exploit living hosts.
 - a. **Parasitism** is a relationship in which one organism, the *parasite*, depends on another, the *host*, for nourishment or some other benefit while simultaneously doing the host harm.
 - b. Parasitism usually does not result in an organism's immediate death.
 - c. Many parasites live in close contact with their hosts, such as disease pathogens, tapeworms, ticks, and lamprey.
 - d. Other types of parasites are free-living and come into contact with their hosts only infrequently (e.g., nest parasites such as cuckoos and cowbirds).
 - e. Some parasites cause little harm, but others may kill their hosts to survive, called *parasitoids*.
 - f. Hosts and parasites can become locked in a duel of escalating adaptations called the evolutionary arms race, resulting in **coevolution**.
 5. Herbivores exploit plants.
 - a. **Herbivory** occurs when animals feed on the tissues of plants.
 - b. Herbivory does not kill the plant, but can affect growth and reproduction.
- C. Mutualists help one another.
1. **Mutualism** is a relationship in which two or more species benefit from interacting with one another.
 2. Many mutualistic relationships—like many parasitic relationships—occur between organisms that live in close physical contact; this is called **symbiosis**.

- a. Free-living organisms such as bees and flowers also engage in mutualism in the process of **pollination**.
- D. Some interactions have no effect on some participants.
 - 1. **Amensalism** is a relationship in which one organism is harmed and the other is unaffected.
 - 2. **Commensalism** occurs when one organism benefits and the other is unaffected.

III. Ecological Communities

- A. Energy passes among trophic levels.
 - 1. As organisms feed on one another, energy moves through the community, from one rank in the feeding hierarchy, or **trophic level**, to another.
 - a. *Producers*, or *autotrophs* (“self-feeders”), comprise the first trophic level.
 - i. Producers include terrestrial green plants, cyanobacteria, and algae, and all of them capture solar energy and use photosynthesis to produce sugars.
 - ii. The chemosynthetic bacteria of hot springs and deep-sea hydrothermal vents use geothermal energy in a similar way to produce food.
 - b. The second level consists of organisms that consume producers (e.g., deer and grasshoppers) are known as *primary consumers*.
 - i. Most of them consume plants and are called herbivores.
 - ii. Examples include deer and grasshoppers.
 - c. The third level consists of *secondary consumers*, which prey on primary consumers.
 - i. Wolves preying on deer are an example of secondary consumers.
 - d. Predators that feed at higher trophic levels are known as *tertiary consumers*
 - i. An example of this is hawks that eat rodents that have eaten grasshoppers.
 - e. Secondary and tertiary consumers are carnivores because they eat animals.
 - f. Animals that eat both plant and animal food are omnivores.
 - g. Detritivores and decomposers consume nonliving organic matter.
- B. Energy, biomass, and numbers decrease at higher trophic levels.

1. At each trophic level, most of the energy that organisms use is lost through respiration.
 2. The first trophic level (producers) contains a large amount of energy, while the second (primary consumers) contains less energy—only that amount gained from consuming producers.
 3. The third trophic level (secondary consumers) contains still less energy, and higher trophic levels (tertiary consumers) contain the least.
 4. A general rule of thumb is that each trophic level contains just 10% of the energy of the trophic level below it, although the actual proportion can vary greatly.
 5. This pattern can be visualized as a pyramid, and also tends to hold for the numbers of organisms at each trophic level, with fewer organisms existing at higher trophic levels than at lower trophic levels.
 6. This same pyramid-like relationship also often holds true for **biomass**: the collective mass of living matter in a given place and time.
 7. Humans can decrease their ecological footprint by eating lower on the pyramid—choosing vegetarianism or reducing meat consumption that takes more energy from the trophic pyramid than a plant-centered diet would.
- C. Food webs show feeding relationships and energy flow.
1. As energy is transferred from species on lower trophic levels to species on higher trophic levels, it is said to pass up a **food chain**, a linear series of feeding relationships.
 2. A **food web** is a visual map of energy flow, showing the many paths by which energy passes among organisms as they consume one another.
- D. Some organisms play bigger roles in communities than others.
1. A **keystone species** is a species that has a particularly strong or far-reaching impact.
 - a. Large-bodied secondary or tertiary consumers are often considered keystone species.
 - b. Predators at high trophic levels can promote populations of organisms at low trophic levels by keeping species at intermediate trophic levels in check. This is called the **trophic cascade**.
 - c. Some species attain keystone species status not through what they eat, but by physically modifying the environment.
- E. Communities respond to disturbance in different ways.
1. Human activities are among the major forces of disturbance in ecological communities worldwide.

2. A community that resists change and remains stable despite disturbance is said to show **resistance** to the disturbance.
 3. Alternatively, a community may show **resilience**, meaning that it changes in response to disturbance but later returns to its original state.
 4. A community may be modified by disturbance permanently and may never return to its original state.
- F. Succession follows severe disturbance.
1. If a disturbance is severe enough to eliminate all or most of the species in a community, the affected site will undergo a somewhat predictable series of changes that ecologists call **succession**.
 - a. **Primary succession** follows a disturbance so severe that no vegetation or soil life remains from the community that previously occupied the site. In primary succession, a biotic community is built essentially from scratch.
 - b. **Secondary succession** begins when a disturbance dramatically alters an existing community but does not destroy all living things or all organic matter in the soil.
 - c. At terrestrial sites, primary succession takes place after a bare expanse of rock, sand, or sediment becomes newly exposed. Species that arrive first and colonize the new substrate are referred to as **pioneer species**.
 - i. Pioneer species, such as lichens, are the first to arrive.
 - ii. Lichens secrete acid, starting the process of soil formation.
 - iii. New, larger organisms arrive, establish themselves, and pave the way for more new species, where eventually a climax community becomes established.
 2. In the traditional view of succession, the transitions between stages of succession eventually lead to a climax community, which remains in place with little modification until some disturbance restarts succession.
- G. Communities may undergo shifts.
1. Today, ecologists recognize that the dynamics of community change are far more variable and less predictable than originally thought.
 2. In addition, climax communities are not determined solely by climate, but rather may vary with soil conditions and other factors from one time or place to another.
 3. Moreover, once a community is disturbed and changes are set in motion, there is no guarantee that the community will ever return to its original state.
 4. A *phase shift* or *regime shift* is where the overall character of the community fundamentally changes.

H. How cohesive are communities?

1. Frederick Clements promoted the view that communities are cohesive entities whose members remain associated over time and space.
2. Henry Gleason maintained that each species responds independently to its own limiting factors, and that species can join or leave communities without greatly altering their composition.
3. Today, ecologists side largely with Gleason, although they see validity in aspects of both ideas.

I. Invasive species pose new threats to community stability.

1. An **invasive species** is a non-native organism that arrives in a community from elsewhere, spreads, and becomes dominant, with the potential to substantially alter a community.
2. Introduced species may become invasive when limiting factors that regulate their population growth are absent.
3. In most cases, ecologists view invasive species as having overall negative impacts on ecosystems.
4. In rare cases, non-native species like the honeybee provide important economic benefits to agriculture and ornamental crops.
5. In case after case, managers are finding that controlling and eradicating invasive species are so difficult and expensive that preventive measures represent a much better investment.

J. Altered communities can be restored.

1. The practice of ecological restoration is informed by the science of restoration ecology, with research into the history of an area as well as an understanding of its “presettlement” condition.
2. Efforts to restore areas to a more pristine habitat are known as **ecological restoration**.
3. Ecological restoration is often time consuming and expensive. A restored system may not match the diversity of the original landscape. It is better to protect natural landscapes from degradation.

IV. Earth's Biomes

A. A **biome** is a major regional complex of similar communities—a large ecological unit recognized primarily by its dominant plant type and vegetation structure.

1. The world contains a number of biomes, each covering large, continuous geographic areas.

B. Climate influences the locations of biomes.

1. A biome depends on a variety of abiotic factors—including temperature, precipitation, atmospheric circulation, and soil characteristics.
 2. Scientists often use climate diagrams, or **climatographs**, to depict annual patterns and monthly averages of temperature and precipitation.
- C. Aquatic and coastal systems also show biome-like patterns.
1. One might consider the shallows along the world's coastlines to represent one aquatic system, the continental shelves another, and the open ocean, deep sea, coral reefs, and kelp forests as still other distinct sets of communities.
 2. Many coastal systems—such as salt marshes, rocky intertidal communities, mangrove forests and estuaries—share both terrestrial and aquatic components.
 3. Freshwater systems such as those in the Great Lakes are widely distributed throughout the world.
- D. We can divide the world into roughly 10 terrestrial biomes.
1. **Temperate deciduous forest** is found in eastern North America and is characterized by broadleaf trees that lose their leaves in the fall.
 2. Moving westward from the Great Lakes, we find **temperate grasslands** that were once widespread but have now been mostly converted to agricultural land.
 3. **Temperate rainforest** is found in the Pacific Northwest and is a forest type known for its high biodiversity and potential to produce large volumes of commercially important products.
 4. **Tropical rainforest** is found in regions near the equator, and is characterized by high rainfall year-round, uniformly warm temperatures, high biodiversity, and lush vegetation.
 5. Tropical areas that are warm year-round but where rainfall is lower overall and highly seasonal give rise to **tropical dry forests**, or *tropical deciduous forests*.
 6. Dry tropical areas across large stretches of Africa, South America, India, and Australia are **savannas**—regions of grasslands interspersed with clusters of trees.
 7. **Desert** is the driest biome on Earth, and much of the rainfall occurs during isolated storms. Deserts are not always hot, but they have low humidity and relatively little vegetation to insulate them. Temperatures, therefore, may vary widely from day to night and across seasons.
 8. **Tundra** is nearly as dry as desert, but is located in cold regions at very high latitudes along the northern edges of Russia, Canada, and Scandinavia. Little daylight in winter and lengthy, cool days in summer

result in a landscape of lichens and low, scrubby vegetation without trees.

9. The northern coniferous forest, or **boreal forest**, often called *taiga*, develops in cooler, drier regions than temperate rainforests. Taigas stretch in a broad band across much of Canada, Alaska, Russia, and Scandinavia.

10. **Chaparral** is found in areas of Mediterranean climate, and consists of densely thicketed evergreen shrubs.

E. Altitude creates patterns analogous to latitude.

1. Not only does temperature drop at progressively higher altitudes, atmospheric pressure (and oxygen) declines too, while ultraviolet radiation increases.
2. Mountains can alter local climates in other ways, such as through the *rainshadow effect*, creating a relatively arid region in the rainshadow region.

V. Conclusion

- A. The natural world is so complex that we can visualize it in many ways and at various scales.
- B. Dividing the world's communities into major types, or biomes, is informative at the broadest geographic scales.
- C. Understanding how communities function at more local scales requires an understanding of how species interact with one another.
- D. Increasingly, humans are altering communities.

Key Terms

amensalism	ecological restoration
biomass	food chain
biome	food web
boreal forest	fundamental niche
chaparral	herbivory
character displacement	interspecific competition
climatographs	intraspecific competition
coevolution	invasive species
commensalism	keystone species
community	mutualism
competition	parasitism
competitive exclusion	permafrost
desert	phytoplankton