5

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 the process of succession

Perceive and predict the potential impacts of invasive species in communities

Explain the goals and the methods of ecological restoration

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 had become gradually cleaner in the years following the Clean Water Act of 1970.

B. Then the zebra mussel arrived; it is native to western Asia and eastern Europe.

C. The zebra mussel's larval stage is well-adapted for long-distance dispersal and they have encountered none of the predators, competitors, and parasites that had evolved to limit their population growth in the Old World.

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D. Zebra mussels can clog up water intake pipes, damage boat engines, degrade docks, foul fishing gear, and sink buoys that ships use for navigation.

E. Zebra mussels also have severe impacts on the ecological systems they invade.

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. Over time, competing species may evolve to use slightly different resources or to use their shared resources in different ways; this is **resource partitioning**.

3. In competitive interactions, each participant has a negative effect on other participants, because each takes resources the others could have used.

B. Predators kill and consume prey.

1. **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*.

2. Predation can sometimes drive population dynamics by causing cycles in population sizes.

3. Predation also has evolutionary ramifications—more adept predators will leave more, healthier offspring, leading to the evolution of adaptations that make them better hunters. The same selective pressure acts on prey species, which evolve defenses against being eaten.

C. Parasites exploit living hosts.

1. **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.

2. Some types of parasites are free-living and come into contact with their hosts only infrequently (e.g., nest parasites such as cuckoos and cowbirds).

3. Many parasites live inside their hosts, such as disease pathogens and tapeworms, while other parasites live on the exterior of their hosts, such as ticks and lamprey.

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4. Hosts and parasites also evolve in response to one another, in a process called *coevolution*.

D. Herbivores exploit plants.

1. **Herbivory** occurs when animals feed on the tissues of plants. In most cases, herbivory does not kill a plant outright, but may affect its growth and reproduction.

E. Mutualists help one another.

1. **Mutualism** is a relationship in which interacting species benefit from one another.

2. Many mutualistic relationships—like many parasitic relationships—occur between organisms that live in close physical contact; this is called **symbiosis**.

3. Free-living organisms such as bees and flowers also engage in mutualism in the process of *pollination*.

III. Ecological Communities

A. Energy passes among **trophic levels**.

1. As organisms feed on one another, matter and energy move through the community, from one rank in the feeding hierarchy, or trophic level, to another.

2. Producers, or autotrophs (“self-feeders”), comprise the first trophic level.

3. Organisms that consume producers (e.g., deer and grasshoppers) are known as *primary consumers*. Most of them consume plants and are called *herbivores*. This is the second trophic level.

4. The third level consists of *secondary consumers*, which prey on primary consumers. Predators that feed at higher trophic levels are known as *tertiary consumers* (e.g., hawks eat rodents that ate grasshoppers).

5. *Detritivores* and *decomposers* consume nonliving organic matter.

   a. Detritivores, such as millipedes and soil insects, scavenge waste products or dead bodies of other community members.

   b. Decomposers, such as fungi and bacteria, break down leaf litter and other nonliving matter into simple constituents that can be taken up and used by plants.

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B. Energy decreases at higher trophic levels.

1. At each trophic level, most of the energy that organisms obtain and use is lost as waste heat through respiration. Only a small portion of the energy is transferred to the next trophic level through predation, herbivory, or parasitism.

2. A rough rule of thumb is that each trophic level contains just 10% of the energy of the trophic level below it.

3. This pattern can be visualized as a pyramid, and it is why eating lower on the food chain—being a vegetarian instead of a meat-eater, for instance—decreases a person's ecological footprint.

4. This pyramid pattern of energy loss from lower trophic levels to higher ones also generally holds for biomass and for numbers of organisms.

C. **Food webs** show feeding relationships and energy flow.

1. A food web is a visual map of feeding relationships and 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.

2. Often, large-bodied secondary or tertiary consumers at the top of the food chain are considered keystone species.

3. Some species attain keystone species status not through what they eat, but by physically modifying the environment, such as beavers and prairie dogs.

4. Less conspicuous organisms, such as fungi that decompose dead matter, and those toward the bottoms of food chains, such as phytoplankton, may have even greater impact.

E. Communities respond to disturbance in different ways.

1. A community that resists change and remains stable despite disturbance is said to show **resistance** to the disturbance.

2. Alternatively, a community may show **resilience**, meaning that it changes in response to disturbance, but later returns to its original state.

F. **Succession** follows severe disturbance.

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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.

2. 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**.

    a. Pioneer species, such as lichens, which are mutualistic aggregates of fungi and algae, are the first to arrive.

    b. Lichens secrete acid, starting the process of soil formation.

    c. New, larger organisms arrive, establish themselves, and pave the way for more new species, and species diversity rises.

3. Secondary succession on land begins when a fire, a hurricane, logging, or farming removes much of the biotic community.

4. Succession also occurs in aquatic systems, and includes the addition of organic matter and sediments from many sources. Eventually, the water body fills in and undergoes a gradual transition to a terrestrial system.

5. In the traditional view of succession, the transitions between stages of succession eventually lead to a *climax community* that remains in place, with little modification, until some disturbance restarts succession.

6. Today, ecologists recognize that succession is far more variable and less predictable than originally thought.

G. **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, potentially able to substantially alter a community.

H. We can try to restore an altered community to its former condition.

1. Efforts to restore areas to a more pristine habitat are known as **ecological restoration**.

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2. 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.

IV. Earth's Biomes

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

2. A biome depends on many abiotic factors, but is determined largely by climate—temperature and precipitation.

3. Scientists often use climate diagrams, or *climatographs*, to depict annual patterns and monthly averages of temperature and precipitation.

A. Aquatic systems also show biome-like patterns

1. The thin strips along coastlines represent one aquatic system.

2. Continental shelves, open ocean, coral reefs, kelp forests, and deep sea regions are other types of aquatic systems.

B. We can divide the world into roughly 10 terrestrial biomes.

1. **Temperate deciduous forest** is found in eastern North America and is characterized by broadleafed trees that lose their leaves in the fall and remain dormant during winter.

2. Moving westward from the Great Lakes, we find **temperate grasslands** that were once widespread but now are mostly converted to agriculture.

3. **Temperate rainforest** is found in the Pacific Northwest and features tall conifers, shaded and damp forest interiors, and fertile soils.

4. **Tropical rainforest** is found in regions near the equator, and is characterized by high rainfall, warm temperatures year-round, and high biodiversity.

5. Tropical areas that are warm year-round but where rainfall is lower overall and highly seasonal give rise to **tropical dry forest**, or tropical deciduous forest.

6. Drier tropical areas across stretches of Africa, South America, Australia, and India 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

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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. They stretch in a broad band across much of Canada, Alaska, Russia, and Scandinavia, and experience long, cold winters and short, cool summers.

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

V. Conclusion

1. The natural world is so complex that we can visualize it in many ways and at various scales.

2. Dividing the world's communities into major types, or biomes, is informative at the broadest geographic scales.

3. Understanding how communities function at more local scales requires understanding how species interact with one another.

4. Increasingly, humans are altering communities.

Key Terms

biome
boreal forest
chaparral
competition
desert
ecological restoration
food web
herbivory
invasive species
keystone species
mutualism
parasitism
pioneer species
predation
primary succession
resilience
resistance
resource partitioning
restoration ecology
savanna
secondary succession
succession
symbiosis
temperate grasslands
temperate rainforest
temperate deciduous forest
trophic levels
tropical dry forest
tropical rainforest
tundra

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Teaching Tips

1. Taking the bioregional approach. That is, examining your home turf based on designations of watersheds, biotic shifts (changes in vegetation), and localized climate, rather than political lines on a map. Use the websites of state or county conservation departments, natural resource management agencies, or other scientifically reliable sources. Have students research which keystone species exist within their local bioregion. Learn what other species are directly dependent upon that keystone species. Consider preparing a display for the school based on this information. If possible, have students discuss the status of this species with local botanists or wildlife biologists and consider a class volunteer effort to restore the habitat conditions that would help this animal or plant.

2. Consider purchasing a program, such as EcoBeaker from Simbiotic Software (www.ecobeaker.com), for use as homework or in a laboratory setting. You can choose how many modules you want to use (currently, there are 20 modules available in EcoBeaker, and six modules in EvoBeaker), and pay for those modules on an annual basis. They require a minimum order of $500 per year at this time. The fees are generally based on the number of students that will use the module, and the number of modules you want to use, in addition to other factors. “Isle Royale” is about the moose and wolf populations on Isle Royale in Lake Superior. It explores predator-prey cycles, logistic and exponential population growth, carrying capacity, and energy flow. “Keystone Predator” recreates Paine’s famous sea star *Pisaster* experiments in the Pacific Northwest. It explores foodwebs, community structure, competition, and keystone species. They will send you a free sampler package of demonstration modules upon request.

3. Ask your students to think of examples of species interactions that are not discussed in the textbook. You may need to guide them through a classic example, such as the commensalism between clownfish and anemones, or the mutualism between oxpeckers and the black rhinoceros.

4. Species in danger of extinction are protected under the Endangered Species Act of 1973. The U.S. Fish and Wildlife Service is the agency that protects listed terrestrial and freshwater species. Information about endangered and threatened species can be found on the U.S.F.W.S. Endangered Species Program website at http://endangered.fws.gov. Using the website, students should be able to find information about local species that are on the list. Have each student choose an organism and do a short paper about the history, current status, and conservation plan, as well as any recent news releases.

5. Rather than teaching about biomes yourself, have your students do a biomes project to learn from each other. In small groups, have them choose a biome or a special subset of a biome, such as dividing wetlands into swamps, bogs, and

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estuaries; dividing deserts into hot deserts and cool deserts; or using ocean shorelines such as sandy shores, rocky (tidepool) shores, and barrier islands.

The groups create a poster or a short PowerPoint presentation, depending on the available time in the course. They need to include, for instance:

World distribution of the biome (include a map)
Major characteristics—elevation, geology, climate, temperature, rainfall, seasonality, and winds
Several representative animals and plants
Indigenous peoples
Two anthropogenic problems that threaten the biome
A table, graph, or chart relating to the biome
A way that is being used to address one of the problems, as well as the results
A listing of resources used for researching the project

Grading should be based upon the satisfactory gathering of the above information, plus a grade on an oral presentation if time permits. The oral presentation should include:
An introduction with a question, humor, or attention-getting fact
Good transitions between presenters and topics within the presentation
Presentation of the material without notes, and using proper pronunciation
Loud, clear voices and good presentation appearance
Good closure, with a summary, a final idea, humor, suggestion for action, or other appropriate ending.

6. The Natural Resources Defense Council (NRDC) has a website with a sub-heading entitled "BioGems." This site spans the planet and highlights the biological diversity, scenic beauty, economic status, and other factors that justify these "BioGems" as worth protecting. Divide students into groups (or have them work in already established groups). Have each group review the BioGem sites online and choose one to study.

   www.savebiogems.org/

   Students can create a program using PowerPoint technology by going directly to the NRDC website to highlight these areas. Students will:

   a. Show a map to place the site within a geographical context
   b. Highlight the unusual biological, geological, and/or cultural features of the "BioGem"
   c. Introduce the site as a potential "Ecotourism" location, explaining why their class members would find this location compelling to visit and worth saving for future generations.

   This activity changes the student's focus from local to global. Both perspectives are necessary for deeper understanding of global biodiversity. This activity can also be dramatic and very enjoyable for students—a "vacation" from typical classroom presentations and lectures.

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Additional Resources

Websites

1. *The World's Biomes*, University of California Museum of Paleontology (www.ucmp.berkeley.edu/glossary/gloss5/biome).

   This Web resource describes the major biomes: aquatic, deserts, grasslands, forests, and tundra.

2. *Invasivespeciesinfo.gov*, National Agricultural Library, United States Department of Agriculture (www.invasivespeciesinfo.gov).

   This website is a gateway to federal and state invasive species programs, activities, databases, and links to primary documents and related websites.

3. *Killer Whales Thinning Otter Population*, 2005, *All Things Considered*, National Public Radio (www.npr.org/templates/story/story.php?storyId=4665067).

   This Web-based audio news report addresses the theory that orca are causing severe decreases in the Alaskan sea otter population.

4. *Society for Ecological Restoration International Online*, Society for Ecological Restoration International (www.ser.org).

   This is the homepage for the Society for Ecological Restoration International, with links to past and existing restoration projects and primary documentation.

5. *The Virtual Nature Trail at Penn State New Kensington*, The Pennsylvania State University (www.nk2.psu.edu/naturetrail/index.html).

   This website uses a virtual tour of a nature trail near the Pennsylvania State–New Kensington campus to provide information about ecological succession.

Audiovisual Materials

1. *Biomes*, 2002, a Cambridge Educational production distributed by Films for the Humanities and Sciences (www.films.com).

   A five-part program that examines biomes as interconnected parts of a global ecosystem. It is available in DVD, VHS, and digital-on-demand formats.

2. *Plants Out of Place: Facing the Green Invasion*, 2001, distributed by Films for the Humanities and Sciences (www.films.com).

   This program illustrates the alarming environmental and commercial impact of non-native invasive plants. It is available in DVD, VHS, and digital-on-demand formats.

3. *Varmints*, 1999, produced by High Plains Films and distributed by Bullfrog Films (www.bullfrogfilms.com).

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This program chronicles the decline of the prairie dog—a keystone species—in the American West.

4. *Interdependence of Life*, 2005, a Cambridge Educational production and distributed by Films for the Humanities and Sciences (www.films.com).

   This program examines the world's ecosystems and explains the flow of energy and the cycling of matter within them.

5. *Living Together: Relationships in the Wild*, 2004, a BBC production and distributed by Films for the Humanities and Sciences (www.films.com).

   This program looks at how relationships between living things have promoted the diversity and splendor of life as it exists on Earth today.

Weighing the Issues: Facts to Consider

Are Invasive Species All Bad?

Facts to consider: A community is a group of populations that interact in specific ways, often due to coevolution. When an invasive species moves in, these relationships are disrupted. Because non-native species are sometimes better competitors for resources because of a lack of factors limiting their population growth, they can cause population reductions and even the extinction of native species that occupy a niche similar to that of the invader. The alien species can also have a huge impact on the entire food web of a community if it is a producer or primary consumer, because it may decrease food resources for native organisms at higher trophic levels. Human intervention may bring in a very large number of invasive species to native communities at a very fast rate, faster than the native species can evolve to adapt to them. A personal response is required to address ethical standards for accepting or rejecting a non-native species in any community.

Restoring "Natural" Communities

Facts to consider: The definition of "natural" will vary among students. The text refers to "historical conditions of ecological communities . . . before our industrialized civilization altered them." However, the question of what constitutes "presettlement conditions" may be a matter of debate. In particular, one must decide how to view environmental changes brought about by preindustrial native peoples. In considering the specific scenario addressed in the question, students could consider historical data that may indicate changes in climatic conditions, vegetative communities and habitat, and other factors that may help indicate whether or not it is feasible to reintroduce species that used to live in the restoration area. Have the climate and environmental conditions changed too much to allow the reintroduced species to thrive? Do the species that were a major part of the historical community still exist? The farther back in time ecologists consider presettlement conditions for a community, the more these questions may affect the restoration effort.

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The Science behind the Story

Inferring Zebra Mussels' Impacts on Fish Communities

Observation: When zebra mussels first invaded the Great Lakes, people feared that fish populations would decrease as the mussels consumed large quantities of the phytoplankton and zooplankton needed by the fish as food. However, after 15 years there was no solid evidence that sports fish populations had been harmed. Research conducted by David Strayer of the Institute of Ecosystem Studies and Kathryn Hattala and Andrew Kahnle of the New York State Department of Environmental Conservation found that while phytoplankton, zooplankton, and open-water invertebrate populations declined by 70%, nearshore (littoral) invertebrate populations increased by 10% or more.

Hypothesis: Introduction of zebra mussels will harm open-water fish populations, but will benefit nearshore feeding fish. Larvae and juveniles of open-water fish species will decrease in number and growth rate, and fish populations will shift away from zebra mussel populations to the saltier water downriver. Larvae and juveniles of littoral fish species will increase in population and growth rate, and fish populations will shift upriver toward zebra mussel populations.

Study: Strayer, Hattala, and Kahnle examined data from three types of fish surveys that were conducted over 26 years and included fish population information prior to and after 1991, when zebra mussels were first introduced to the Great Lakes.

Results: All the data analyzed supported the researchers' hypotheses. On a larger scale, the study confirmed the hypothesis by correlating fish communities and changes in food resources. However, it should also be noted that correlation does not prove causation, and that the cause of the changes in fish population size, growth rate, and location is not clearly shown by this study.

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