

BIG IDEAS:

- Organisms compete for limited resources.
- Competition affects the growth, survival and reproduction of the organisms involved.
- A species' niche describes its way of life and role in an ecosystem.
- Two species cannot have the same niche in an ecosystem.
- Exploitation benefits one organism but harms another.
- Adaptations help organisms exploit other organisms or avoid being exploited.
- Commensalism benefits one organism but does not affect another.
- Mutualism benefits each organism that participates in the interaction.
- Interactions maintain balance within ecosystems.

Interactions AMONG ORGANISMS

On a mudflat, little birds with long legs skitter along the water's edge. The oozy mud and mucky water are a virtual insect soup, and the birds—famished from a long migration—eat quickly and greedily. Although the scene looks peaceful, there is an intense competition raging with shorebird pitted against shorebird, each trying to gather enough to eat before the supply of insects runs out.

At the edge of a marsh, a mink and a muskrat are locked together in mortal combat. The mink, trying to find a killing hold, bites the muskrat's neck. The muskrat shakes off the mink. Fur flies. The mink springs back at the muskrat, and the two tumble, snarling and squealing, through the vegetation. For the mink, victory means a full belly; for the muskrat, victory means survival.

Along a weedy fencerow, a bumblebee touches down on the lavender blossom of a milkweed plant. For the plant, the bumblebee is a delivery driver, transferring pollen from one flower to another, thereby ensuring a future crop of milkweed. For the bee, the flower is a grocer, providing nectar to make honey, thereby ensuring food for the next generation of bumblebees.

These are just a few of the countless interactions that occur among organisms in nature. Ecologists define an **interaction** as a relationship between two or more organisms that affects the growth, survival or reproduction of the participants. Ecologists categorize interactions as competition, exploitation or mutualism based on the costs and benefits resulting from the relationship. **Competition**—perhaps the most common interaction in nature—occurs when neither organism benefits from the interaction. **Exploitation** occurs when one organism benefits, while another organism is harmed from the interaction. **Mutualism** occurs when both organisms benefit from the interaction. In this chapter, we will explore competition, exploitation and mutualism and examine how these interactions affect the participants involved.

Organisms compete for limited resources.

Shorebirds are the marathoners of the bird world. Although many birds migrate, shorebirds fly extreme distances between their nesting and wintering grounds. Take, for instance, the American golden-plover, which nests in the Arctic tundra, yet winters in Argentina. The roundtrip flight between these two locations averages 25,000 kilometers—not bad for a bird the size of a robin. During migration, plovers often zip through the air at altitudes of 6,000 meters and speeds faster than you can legally drive on the interstate. When crossing oceans, they have been known to fly nonstop for two days! You couldn't pump enough fuel into a jumbo jet to accomplish the same feat.

To fuel their epic migrations, golden-plovers and other shorebirds need to eat—a lot. And, nothing satisfies the appetite of a hungry shorebird more than a slew of squirming mosquito larvae, leeches or other aquatic invertebrates. The best places to find such fare are the mudflats and shallow pools that dot the Midwestern landscape. Mudflats, however, are hard to find. Sometimes they are covered by floods; other times they are baked dry by drought. Most are small and spaced far apart. Because of this, shorebirds often concentrate in whichever tiny mudflat they can find. And, as you might expect, competition for food in these muddy pools is intense.



American golden-plovers migrate long distances between nesting and wintering grounds.



Mudflats in the Midwest are small and far apart. Consequently, competition for food among shorebirds is intense.

Ecologists define **competition** as a struggle among organisms to use or consume a limited resource. Because every organism needs certain resources to grow, survive and reproduce, competition is common in nature. Sometimes competition involves organisms trying to gather as much as they can of a shared resource before it runs out. Shorebirds foraging in a mudflat, fish slurping up a hatch of mayflies, squirrels gathering acorns in a park—all are examples of what ecologists call **indirect competition**. At other times, organisms actively take or defend a resource from other organisms. In the fall, blue jays often harass squirrels—sometimes by pecking the squirrel on the head—to steal acorns. Competition isn't limited to just animals, either. Trees in a forest compete for sunlight. Fungi on a rotting log compete for space. The bacteria living in your gut compete for nutrients. In nature, whenever and wherever resources are limited, competition will occur.

Often, members of the same species compete with each other for limited resources. At a mudflat, each American avocet competes with other avocets for aquatic insects to eat. On the nesting grounds, avocets compete with each other for mates and nesting sites. This kind of competition among members of the same species is called **intraspecific competition**. When competition involves different species—such as when avocets compete with sandpipers, yellowlegs and stilts for food—ecologists call it **interspecific competition**.



American avocet



Pectoral sandpiper



Greater yellowlegs



Black-necked stilt



Gathering resources exposes organisms to predators.

Competition affects the growth, survival and reproduction of the organisms involved.

Imagine being adrift in a life raft with 10 other people. You have enough food to last for a few days, but each time someone eats, there is less food left for everyone else. The same thing happens in nature. When a resource is limited, each time an organism consumes part of the resource, a smaller amount is left for others to use. As organisms continue consuming the resource, over time it becomes scarce. When resources become scarce, competition becomes fierce. And, when competition is fierce, life gets tough for the organisms involved.

When resources are scarce, competition can affect the growth of organisms. Imagine you're planting flowers in two equally sized pots. As an experiment, you plant five flowers in one pot, and 10 flowers in the other pot (*Figure 4.1*). Both pots contain the same kind and amount of soil, both are placed so that the plants receive the same amount of sunlight, and you give each pot the same amount of fertilizer and water. Which pot's flowers do you think will grow better? If you said the pot with five flowers in it, you'd be right. Ecologists have done many versions of this experiment, and the results are always the same: When a greater number of organisms compete for the same amount of resources, the growth of each organism is diminished.

Competition for scarce resources can affect the survival of some organisms. If organisms don't get enough to eat or drink, they will eventually die. Competition for food can cause organisms to spend more time foraging. This is risky because it exposes organisms to predators more than if they were hiding or sleeping. Competition for space can affect survival by causing some organisms to use marginal habitats where they might be more exposed to weather and predators.

When resources are scarce, competition can affect the reproduction of some organisms. To reproduce, female shorebirds must consume enough food during their northward migration to survive, power their flight to the nesting grounds, and produce eggs. When competition forces a female shorebird to go hungry, her odds of survival and ability to reproduce are diminished.

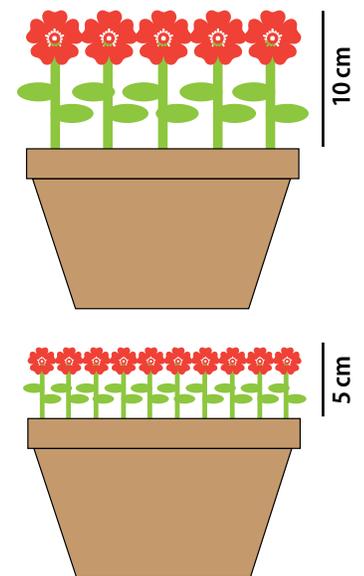


Figure 4.1—When fewer organisms compete for resources, their growth increases. When more organisms compete for the same amount of resources, their growth is diminished.



Timber Stand Improvement

Take a moment to consider the products you've used today, and it's likely more than half of them came from trees. Some are obvious. The pages in this book, the lumber framing your school, the tissue you blew your nose in—all come from trees. Some of them aren't so obvious. Clothing fabrics, carpeting, cosmetics, even the circuit boards in your laptop—these, too, come from trees. In total, about 5,000 products—from charcoal to chewing gum—come from trees.

Fruits, nuts and other products can be obtained from living trees. To get most products, however, trees must be cut down. Harvesting trees in Missouri, when done in a responsible manner, can provide wildlife habitat and forest products for generation after generation. Missouri's trees are a renewable resource but, like other crops, must be managed properly to produce a high-quality product in a reasonable amount of time. Foresters use what they know about competition and how it affects different tree species to make wise management decisions.

After harvest, new trees quickly recolonize the openings created in the forest. In these areas, 10,000 to 12,000 seedlings may grow on a single hectare. Competition for sunlight and moisture is fierce. Unless some of the seedlings are thinned out, all the seedlings grow slowly and poorly. Over time, a few of the strongest seedlings may outcompete their rivals, sending branches higher to gather sunlight or roots deeper to collect water. Without enough sunlight or water, weaker trees eventually die. In addition, herbivores, pests and disease thin out a proportion of the seedlings. When the trees are large enough to harvest again, the forest will have fewer than 250 trees per hectare. This natural thinning usually takes 150 to 250 years depending on the type of trees.



Foresters cut down unwanted trees to reduce competition and improve a stand of timber.

Using special management techniques, foresters can reduce this time span to less than 100 years and improve the health and quality of the surviving trees. One of the techniques foresters use is called **timber stand improvement**. To improve a stand, or segment of the forest, foresters remove unwanted or low-value trees and those with crooked or damaged trunks. They leave desirable trees that have tall, straight trunks free from insect, disease and fire damage. By reducing competition for sunlight and water, this technique allows the desirable trees to grow faster and produce higher-quality wood. With less energy needed for competition, trees that remain can devote more energy to surviving diseases and fighting off pests. They also have more energy for reproduction, so nut and seed production typically increases. This provides extra food for wildlife and a seed source for the next generation of trees.

A species' niche describes its way of life and role in an ecosystem.

Imagine you are a world-renowned expert on the greater yellowlegs, a species of shorebird that migrates through Missouri in the spring and fall. If I asked you to tell me everything you know about yellowlegs, our conversation might stretch on for days. We might begin by talking about the range of environmental conditions that yellowlegs can tolerate—what temperature extremes they can survive, how much humidity they can handle, at what altitude they can nest and fly. Then you might continue with what yellowlegs need to grow, survive and reproduce. What foods yellowlegs eat might take several hours to describe, as would their nesting requirements—what habitats they use, where they place their nest, how they hide the nest, what materials they use to build the nest, blah, blah, blah. We might wrap up by talking about how yellowlegs interact with their environment and other species in it. You'd tell me which species yellowlegs compete with for food and nesting sites, which species are predators of yellowlegs, and what role yellowlegs play in the ecosystems they inhabit.

Everything you've described about greater yellowlegs is a part of its **niche**. To an ecologist, a niche describes everything affecting a particular species' existence, including the range of environmental conditions the species can tolerate, what the species needs to grow, survive and reproduce, and how the species interacts with its biotic and abiotic environment. In other words, the niche describes a species' way of life and its role in an ecosystem.

A species' **fundamental niche** includes the environmental conditions the species can tolerate and the resources it is capable of using under ideal conditions. In nature, however, conditions are rarely ideal. Other species may compete for the same resources or be predators. Competition and predation may cause a species to use only part of the resources that make up its fundamental niche. This more restricted range of resource use is known as the species' **realized niche**—the portion of the fundamental niche a species uses in the presence of other species. For example, greater yellowlegs are capable of gathering food anywhere on a mudflat from the shoreline to water 4 inches deep. When different species of shorebirds use a mudflat, though, yellowlegs typically forage in water 3 or 4 inches deep, leaving shallower or deeper areas to other species that are more efficient at gathering food there (*Figure 4.2*).

Understanding niches helps us understand how species interact with each other. Species with similar niches are more likely to compete for resources, while species with dissimilar niches are less likely to compete for resources.

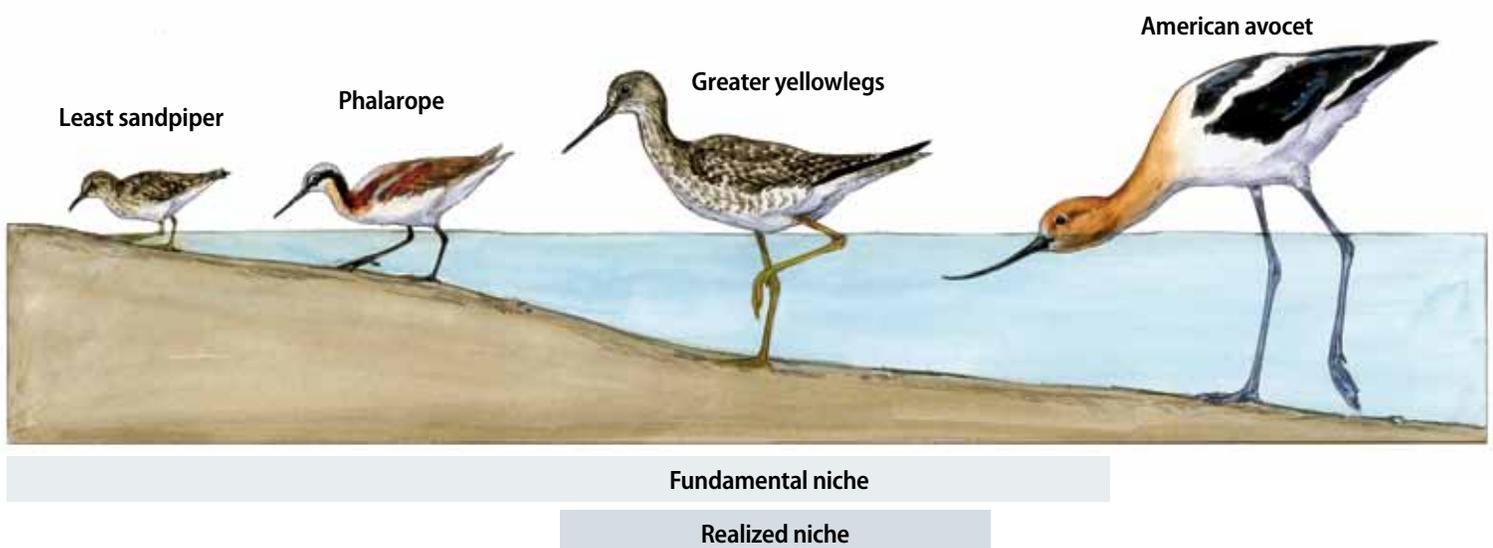


Figure 4.2—A species' fundamental niche is always broader than its realized niche. Under ideal conditions, greater yellowlegs can forage from the shoreline to water 4 inches deep. However, competition with other shorebirds often causes yellowlegs to gather food in water 3 or 4 inches deep.



Managing Wetlands

Ask a resource manager about wetlands, and the word “dynamic” is bound to come up. By this, the manager means wetlands change a lot. Wetlands are wet—most of the time. Sometimes, however, they dry out. Other times, they flood. A wetland after a spring deluge looks quite different than the parched mud hole of a mid-summer drought.

The land in a wetland seems flat, but isn't. Within wetland pools, mounds of high ground border shallow sloughs, adding additional variety to the landscape. These small differences in elevation, combined with the ebb and flow of water, create an ever-changing patchwork of habitats that fulfill the niche requirements of a variety of organisms, from mallards to muskrats.

More than 85 percent of Missouri's historic wetlands are gone. Many were drained. Others dried up when rivers were channelized and flood-control levees were built. During the last 50 years, many government agencies, nonprofit groups and private landowners have worked hard to restore wetland habitats. Today, the

Wetland managers use water-control structures to mimic the ebb and flow of water that occurs on a natural wetland.



Conservation Department manages more than 45,000 hectares of wetlands throughout the state. Many of these wetlands require intense management to mimic the natural ebb and flow of water that occurs in unaltered wetlands. Managers use a system of pumps, canals and water-control structures to do this.

Often, managers begin flooding wetland pools in late summer. As the water slowly creeps across the pool, it creates mudflats for migrating shorebirds and shallowly flooded vegetation, which attracts blue-winged teal. By October, the water is a little deeper and covers more of the pool, providing resting and feeding areas for large flocks of dabbling ducks, such as mallards, that dip their heads underwater to strain seeds, vegetation and aquatic insects through their bills. The deeper water also affords turtles and frogs a place to hibernate through the winter. By mid-winter, if it's not frozen over, the water is at its deepest and provides areas for diving ducks, such as scaup, redheads and canvasbacks, that swim underwater to catch food.

In early spring, flooded vegetation begins to decompose, providing homes and food for a flush of aquatic insects. Waterfowl come back through Missouri around March and feast on the insects. After ducks and geese depart in late spring, managers begin slowly drawing water off wetland pools. As the water recedes, it exposes mudflats for shorebirds, provides breeding pools for frogs and salamanders and disperses the seeds of wetland plants. The various water depths and exposed areas provide niches for different plants to germinate and grow. Ground exposed in early May might foster smartweeds, while ground exposed in mid-May might give rise to wild millet. To meet the niche requirements of the greatest number of plants, wetland managers try to take water off a pool slowly.

Sometimes managers leave pools flooded throughout the summer. This provides spawning grounds and aquatic nurseries for fish. When the wetlands dry up later in the summer, the fish become concentrated into ever-shrinking pools. This provides easy pickings for young herons and other wading birds newly abandoned by their parents and just learning to hunt for themselves.

Resource managers will never be able to improve upon nature. However, by manipulating how deep, how long and when wetland pools are flooded, managers can meet the niche requirements for a vast array of species. Pretty dynamic, wouldn't you say?

Two species cannot have the same niche in an ecosystem.

In 1932, a 22-year-old Russian student named Georgyi F. Gause performed a series of brilliant experiments that turned the field of ecology on its head. Gause wondered what would happen when species with similar niches competed for the same resource. To find out, he carefully measured the population growth of two different *Paramecium* species. He started by growing the two species in separate beakers of water, and both populations thrived. When he grew both *Paramecium* species in the same beaker, however, one population always survived, while the other always died. Gause concluded that one species was better at competing for food, which caused the other species to eventually die. These results led Gause to form the **competitive exclusion principle**, which states that two species with identical niches cannot coexist over time. This theory—also called Gause’s Law—is a key idea of ecology.

Competitive exclusion predicts that when two species compete for exactly the same resources, one will be more efficient than the other at gathering those resources. This will cause the more efficient species to fill the niche with more of its offspring, eventually leaving no resources for the less efficient species. With no resources to use for growth, survival and reproduction, the less efficient species eventually dies off. This explains why two species cannot have the exact same niche in an ecosystem.

Species can have *similar* niches and coexist, but not *identical* niches. Close observation of two similar species usually reveals subtle differences in what each eats, how each gathers food, where each nests, or some other aspect of each species’ lifestyle. These subtle differences are often enough to allow two similar species to coexist in the same ecosystem. For instance, different species of shorebirds can often be found foraging on the same mudflat. Since each shorebird desperately needs to refuel, and since each seems to be going after the same kinds of food, you might think competitive exclusion would come into play. If you were to carefully observe the shorebirds, though, you would notice several differences in where each species forages and how each captures food. Long-legged avocets forage in water 6 inches deep, swinging upturned bills side to side to snag minnows and swimming invertebrates. Water 4 inches deep might attract greater yellowlegs, while phalaropes can be found foraging in water 2 inches deep. Least sandpipers might be found running along the water’s edge, probing in mud with their bills for snails, worms and insect larvae (Figure 4.2). By foraging in different places and catching prey in different ways, shorebirds lessen competition and avoid competitive exclusion. When species with similar niches use a resource in slightly different ways, ecologists call it **resource partitioning**.

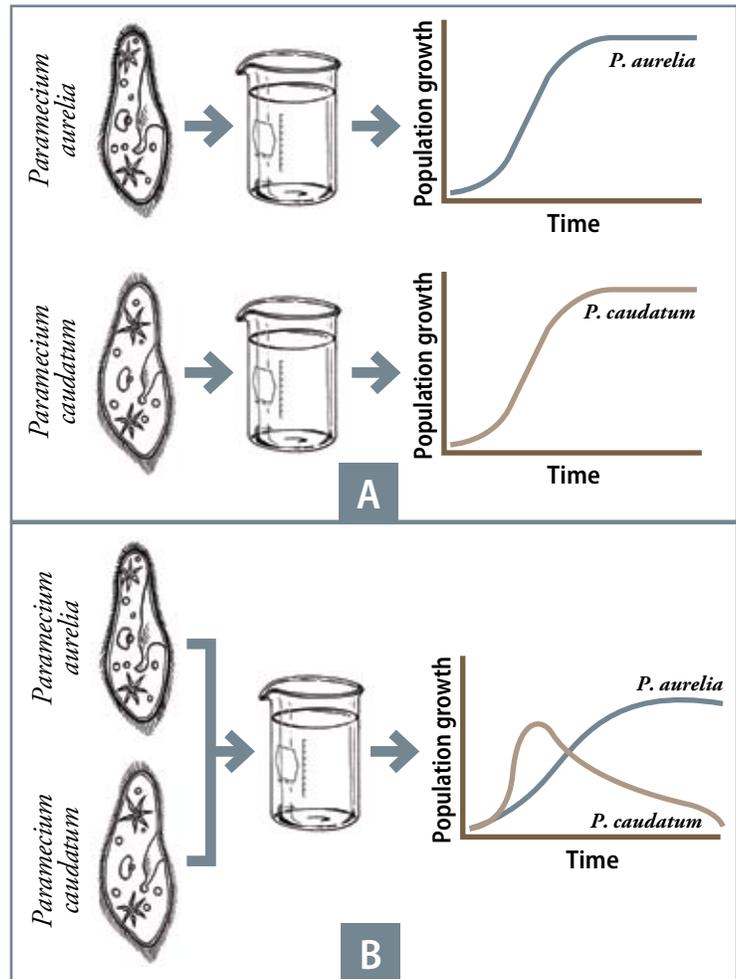


Figure 4.3—When Gause grew two *Paramecium* species in separate containers, both thrived (A). When he grew both species in the same container, one survived and the other died (B).



American avocets forage in water too deep for most shorebirds to use.



Predators, like this bobcat, get energy by eating other animals.



Herbivores, like rabbits, get energy by eating plants.



Parasites, like ticks, get energy by feeding on their hosts.

Exploitation benefits one organism but harms another.

In nature, every organism needs energy, and nearly all organisms risk becoming energy for something else. **Predators** get energy by catching, killing and eating prey. A bobcat eating a rabbit and a bat eating a moth are both examples of predation. **Herbivores** get energy by eating plant parts. A rabbit clipping clover is an example of herbivory. **Parasites** get energy by feeding on the blood, intestinal fluids or tissues of another organism, called the **host**, usually without killing it. Some parasites, such as ticks and leeches, live on the outside of their hosts. Other parasites, such as tapeworms, live inside their hosts. While each of these interactions—between predator and prey, herbivore and plant, and parasite and host—is slightly different, they all have one thing in common: One organism benefits from the relationship, while the other organism is harmed. Ecologists often group these kinds of interactions together and call it exploitation. Whenever one organism makes its living at the expense of another, exploitation occurs.

Predators, herbivores and parasites can be limiting factors on other populations. By killing or weakening the organisms they exploit, predators, herbivores and parasites increase deaths and decrease births in prey, plant and host populations. Likewise, shortages of prey, plants and hosts can lead to starvation or malnourishment in predator, herbivore and parasite populations.

Adaptations help organisms exploit other organisms or avoid being exploited.

Predators have a stunning arsenal of senses to help them find prey. Some predators, particularly birds of prey, have keen eyesight that helps them detect animals to eat. A red-tailed hawk can spot a rabbit scratching its ears 2 kilometers away. Many predators, from coyotes to catfish to copperheads, use smell and taste to locate prey. Catfish are known as swimming tongues because nearly every part of their bodies—from their cat-like barbels to the tips of their tails—is covered with taste buds. (If you were a catfish, you could taste a cookie just by touching it.) This, coupled with a highly developed sense of smell, helps catfish find food in dark, muddy water. Many nocturnal predators find prey using only their hearing. The flat, concave shape of a barn owl's face acts like a radar dish to help guide the quietest of sounds to its ears. By judging the time difference between when the sound is heard in its left and right ear, barn owls can determine the exact location of a squeaking mouse in complete darkness.

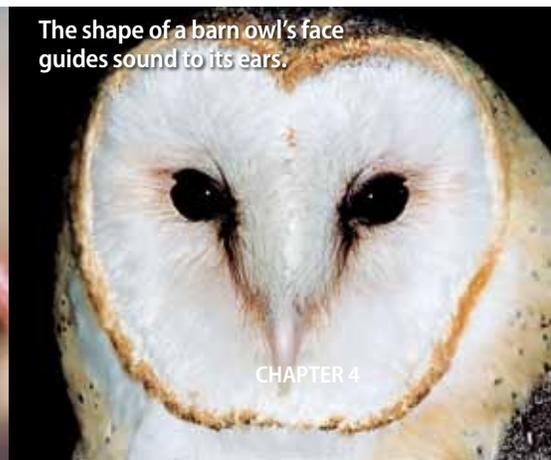
Red-tailed hawks use keen eyesight to spot prey.



A copperhead uses heat sensors in its head to detect prey.



The shape of a barn owl's face guides sound to its ears.





Thwarting a Different Kind of Parasite

Not all parasites make their living by feasting on other organisms. Ecologists have a much broader definition for parasite. It includes organisms that take advantage of their hosts in other ways. For instance, brown-headed cowbirds are notorious **brood parasites**. Instead of building their own nests and raising their own chicks, cowbirds lay their eggs in the nests of other birds. The other birds raise the cowbird chicks,

which hatch earlier and grow faster than the parents' own young. Because cowbird chicks are bigger, they can reach higher to snatch food from the parent before other chicks can get it. Sometimes, this causes the smaller chicks to starve. Other times, cowbird chicks physically force smaller chicks out of the nest.

Cowbirds parasitize more than 220 different bird species, ranging from tiny chickadees to large ducks. Not all birds make good foster parents. If a yellow warbler finds a cowbird egg, it either abandons its nest or builds another nest on top of the first one. This kills the cowbird egg. Yellow warblers may stack several nests on top of each other, each one containing a cowbird egg. Prairie birds, which have adapted to cowbird parasitism over time, are more likely to kick cowbird eggs out of their nests. Forest-dwelling birds, which were not historically exposed to cowbirds, suffer the most. When their nests are parasitized, most parent birds wind up losing their own young and raising only cowbird chicks.

Because cowbirds quit laying eggs in mid-July, some birds are able to re-nest later in the summer and raise their broods free from cowbirds. Many species, however, migrate long distances and only have time to pull off one nest. If their first clutch is lost to cowbird parasitism, no young will be produced until next year's breeding season. As most birds live only a few years, this can lead to long-term population declines.

Prior to European settlement, cowbirds were nomadic, following immense herds of bison to feed on the insects the bison stirred up. When bison were wiped out and replaced by domestic livestock, cowbirds adapted to a more sedentary lifestyle. They now frequent woodland edges near pastures and crop fields. The clearing of forests has provided additional habitat for cowbirds and allowed them to expand into areas where they previously were absent. In large tracts of forest, however, cowbirds are rare because of the lack of open areas to forage in. As such, cowbird parasitism seems to depend on the landscape in which the host's nest is located. Nests in extensive forest or prairie landscapes sustain less parasitism, while those in fragmented forests interspersed with pastures and croplands are heavily parasitized.

This is important information for resource managers. In some parts of the country, managers trap and kill adult cowbirds and spend considerable time removing cowbird eggs from host nests. Scientists, however, believe these efforts have limited success. Although they might be effective on a local scale for helping rare and endangered species, killing, trapping and egg removal are not cost effective or successful on a large scale. Instead, most managers believe that the key to keeping cowbirds at bay has to do with habitat. Keeping large forests, like those in the Ozarks, from being divided into smaller tracts is the best way to reduce cowbird parasitism and increase the reproductive success of forest-dwelling birds.



Brown-headed cowbirds are nest parasites, laying their eggs in the nests of other birds.

Some predators have senses that humans don't. Most fish have a lateral line that runs down each side of their body from head to tail. This line of sensory cells can feel vibrations in the water, helping a fish find floundering prey. Bats use a kind of natural radar called echolocation to hunt and navigate in the dark. They emit high-frequency sounds that bounce off objects in the distance. By interpreting the echoes, bats can locate insects to eat and find their way through pitch-black caves. Pit vipers, such as copperheads and rattlesnakes, have heat sensors in their heads that detect the presence of warm-blooded birds and mammals on a dark night.

Predators lead a tough life, and finding prey is only half the task. Once prey is found, it must be captured and killed, and all predators are armed with adaptations to do this. Bobcats have hook-like claws that help them latch on to prey and long canine teeth to puncture the throat or spinal cord of animals, such as rabbits. Scorpions, venomous snakes and a tiny, mouselike mammal called the short-tailed shrew all use venom to subdue prey. Some animals—called ambush predators—hold very still, waiting for prey to come close enough so they can quickly strike. Great blue herons use this strategy, shading shallow water with their wings. When an unlucky fish swims by, the heron plunges its dagger-like bill into the water to snatch it up. Some predators work together to capture prey. White pelicans swim together to herd fish into shallow water, and coyote families hunt together to bring down large prey.

Prey organisms have adaptations that help them avoid detection or evade capture by predators. Many prey animals, such as walking sticks, rough green snakes and deer fawns, have shapes, colors and patterns that help them to blend in with their surroundings. Other species use noxious chemicals to keep predators from eating them. These species, such as monarch butterflies, striped skunks, and bumblebees, typically advertise their poor taste, foul smell or poisonous flesh with **warning coloration**. Bold patterns and bright colors are nature's way of saying, "I'm not good to eat."

Some harmless animals masquerade as distasteful or dangerous animals. Several species of clear-winged moths don't have stingers, but look and act just like wasps that do. When a harmless organism (called a



Clockwise from above—A striped skunk's bold black and white fur is an example of warning coloration. Although harmless, the hummingbird moth's black and yellow colors mimic the appearance of a bee or wasp. This is an example of Batesian mimicry. An example of Mullerian mimicry, a viceroy butterfly looks nearly identical to a monarch butterfly. Both taste bad, and predators that eat one likely will not try to eat the other.



mimic) resembles a dangerous organism (called a **model**), ecologists call the relationship **Batesian mimicry**. Batesian mimicry only works when the harmful species outnumbers the harmless copycats. If too many copycats are around, predators quickly learn that the warning coloration is a trick, and begin eating both mimics and models.

Another type of mimicry, called **Müllerian mimicry**, occurs when dangerous or distasteful species resemble each other. Many species of bees and wasps employ the same pattern of yellow and black stripes to let predators know that they can sting. Monarch and viceroy butterflies look nearly identical and taste equally bad. By exhibiting the same orange and black color patterns, predators that try to eat a monarch usually don't repeat the experience with viceroys or other monarchs.

Many prey animals, such as rabbits and deer, are exceptionally fast and use their speed to avoid capture. Slower animals, such as turtles and armadillos, have shells or bony plates that help protect them from attack. Some prey species seek safety in numbers by gathering in herds, flocks or schools. This way, they have more eyes to watch for predators, and only individuals at the edge of the group are likely to be captured. Other prey species try to confuse or scare away predators. When a predator approaches an eastern hog-nosed snake, the snake puffs out its head like a cobra, hisses loudly and strikes. If this doesn't work, the hog-nosed snake rolls over on its back, writhes about, and plays dead. This acting job usually helps the snake avoid becoming a meal.

Plants employ structures or chemicals to defend against herbivores. Many plants, such as honey locusts, prickly pears and blackberries, have thorns or spines that make a herbivore think twice before taking a bite. Prairie grasses contain silica in their leaves and stems. This mineral—the same one found in sand and glass—makes the grasses hard to digest and wears down the teeth of herbivores. Many plants produce bitter or poisonous chemicals to keep herbivores at bay. Oak trees produce tannins that make their bark and foliage taste bitter. Milkweed—a common roadside wildflower—not only tastes bad, it also produces cardiac glycosides, a group of chemicals that alter heart rhythms. If enough milkweed is ingested, it can kill birds and mammals—even those as large as deer.

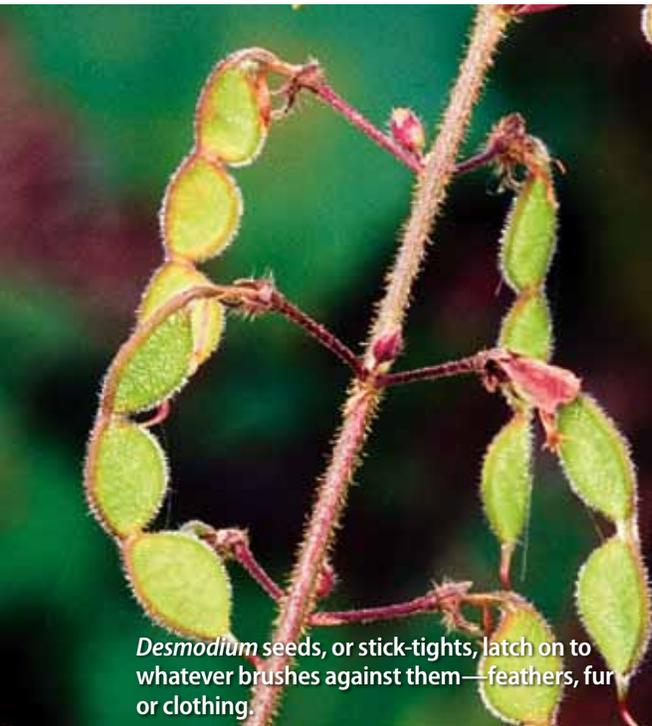


Clockwise from left—Little bluestem contains silica, a mineral that wears down the teeth of herbivores and is hard to digest. White-tailed deer counter this defense with teeth that have large surfaces to grind and pulverize tough plant tissues. A harmless hog-nosed snake tries to confuse a predator by flattening its head like a cobra's, hissing loudly and striking.

Herbivores use a number of adaptations to counter a plant's defenses. White-tailed deer, like many herbivores, have teeth with large surfaces to grind and pulverize tough plant tissues. Animals, however, can't digest cellulose, a major component of plant tissue. To get around this biological snag, herbivores maintain colonies of bacteria, protozoans and yeasts in their digestive tracts. These microorganisms use special enzymes to break down cellulose, providing an energy-rich meal for themselves and the herbivores they live inside. Some herbivores, like cottontail rabbits, take digestion one step further—they eat their own droppings. By allowing plant materials to pass through their digestive tracts twice, rabbits can more thoroughly absorb all the nutrients found in the plants they eat. Eating droppings has another advantage: young rabbits acquire the microorganisms needed to break down cellulose from eating their mother's pellets.

Some herbivores use plant poisons for their own benefit. Monarch butterflies lay their eggs only on milkweed. Caterpillars eat the milkweed leaves and store the milkweed's cardiac glycosides in their body tissues. When the caterpillars turn into butterflies, they retain the milkweed's poisons, causing adult monarchs to have a terrible, bitter taste. This keeps predators from eating monarchs. Birds that swallow a monarch usually vomit it back up within a few seconds and rarely make the mistake of eating a monarch again.

Parasites have adaptations that help them find, feed on and disperse from their hosts. From 100 meters away, mosquitoes can zero in on an unlucky camper by following the scent of the carbon dioxide he breathes out. From 3 meters away, mosquitoes can detect the heat from his blood. Like leaches and ticks, most parasites have either sucking mouthparts or hooklike appendages that keep them attached to their hosts. Many parasites—especially internal parasites—don't leave once they find a good host to exploit. They do, however, face a tough challenge in finding a new host for their offspring (after all, an intestine can only hold so many tapeworms). To increase the odds that at least a few of their young will survive, most parasites produce a staggering number of offspring. It's been estimated that a single liver fluke can produce four hundred million offspring over its lifetime. Many parasites have elaborate life cycles that involve several intermediary hosts before the offspring wind up in their final host. For example, the protozoan responsible for causing malaria in humans spends part of its life in the saliva of mosquitoes.



Desmodium seeds, or stick-tights, latch on to whatever brushes against them—feathers, fur or clothing.

Ted Bodner, Southern Weed Science Society, Bugwood.org

Commensalism benefits one organism but does not affect another.

Watch a herd of cattle grazing on a pasture, and you might notice a little brown bird hopping through the grass at their feet. The bird, called a brown-headed cowbird, can be found in grasslands throughout the Midwest, wherever there are cattle or bison. The reason they stick close to cattle is simple—cowbirds are looking for an easy meal. As cattle move from plant to plant, they stir up insects, which become easy prey for the cowbirds. In this relationship, the cowbirds benefit from their interaction with the cattle. The cattle, however, are neither harmed nor benefit, and are mostly unaffected by the cowbirds. Ecologists call this kind of interaction—where one organism benefits and the other is unaffected—**commensalism**.

If you've ever walked through a weedy field in the fall you've probably been an unwitting participant in an act of commensalism. *Desmodium* is a plant that has seeds covered with a Velcro-like substance. The seeds, or stick-tights, latch on to whatever brushes against them. Although they are a hassle to pick off clothing, the seeds don't really harm you

or the animals they stick to. *Desmodium*, however, benefits from the interaction by having its seeds carried away from the parent plant. This lowers the chance the offspring might compete with the parent for water, nutrients and other resources.

Ecologists differ on what they consider commensalism. Some ecologists think commensalism should include any instance where one organism benefits and another is unaffected. In this view, a robin nesting in a maple tree is a commensal interaction, because the robin benefits from the shelter the tree provides, while the tree is unaffected by the robin's nest. Other ecologists only consider an interaction to be commensalism when the benefiting organism cannot survive without the other species. In this narrower view of commensalism, because the robin can nest in many different kinds of trees, the relationship between the bird and the maple is not commensal. If, however, robins relied solely on maple trees to hold their nests, then the relationship would be an example of commensalism. Some ecologists believe that pure commensalism does not exist at all. These ecologists argue that any close relationship has to be slightly beneficial or harmful to the organism originally thought to be unaffected. Take, for instance, the relationship between cowbirds and cattle. Some ecologists would point out that by eating insects that parasitize cattle, cowbirds actually help the cows. When looked at from this point of view, both organisms benefit, a type of interaction called mutualism.

Mutualism benefits each organism that participates in the interaction.

Many interactions between organisms benefit both participants. Bees disperse a flower's pollen in return for a meal of nectar. The bacteria living in a rabbit's gut break down and release energy from cellulose. In return, the microorganisms get a steady supply of food and a warm place to live. Fungi living on the roots of an oak tree help the tree gather nutrients from the soil. The tree uses the nutrients to build sugars, which it shares with the fungi. In each of these relationships, both participants benefit, a situation ecologists call **mutualism**.

Mutualism can benefit the participants in different ways. Mutualism can help participants gather food and energy more efficiently. Lichens, those mossy-looking organisms that grow on rocks and bark, are actually two separate organisms. One is a fungus that specializes in gathering nutrients from the surface on which it grows. The other is an algae that specializes in turning sunlight into usable energy. The fungus provides the algae with nutrients for photosynthesis, and the algae provide the fungus with energy. The relationship between herbivores and the microorganisms in their guts also fall into this category of mutualism.

Mutualism can help one of the organisms reproduce. Ever wonder why blackberries often grow along a fence? It's because birds eat blackberries, which contain seeds. Some of these seeds pass through the birds' guts undigested. Birds use fences for perches and leave droppings containing undigested seeds along the fence row. In this relationship, the bird gets a sugary meal, and the blackberry gets its seeds dispersed with the droppings as fertilizer. Many fruit-bearing plants disperse seeds in this manner. Pollinators and nectar-producing plants are another example of this category of mutualism.

Mutualism can increase the safety of the participants. Remember Müllerian mimicry, when dangerous or noxious organisms display similar colors and patterns, such as bees and wasps that all have black and yellow stripes? If a predator gets stung by



A bumblebee transports pollen from one flower to another as it gathers nectar.

Russ Ottens, University of Georgia, Bugwood.org

Type of Interaction	Examples	Outcomes for the Organisms Involved
Competition	Intraspecific	Lose/Lose
	Interspecific	Lose/Lose
Exploitation	Predation	Win/Lose
	Herbivory	Win/Lose
	Parasitism	Win/Lose
Commensalism		Win/No Effect
Mutualism		Win/Win

Table 4.1—Interactions Among Organisms (*Blue shading indicates symbiosis.*)

one species in this group of mimics, it learns to avoid the other species in the group. By looking like each other, all the bees and wasps are safer than if each looked different.

When two organisms have such a close relationship that one could not survive without the other, ecologists refer to the partnership as **symbiosis**. Rabbits could not gather enough nutrients from the plants they eat without the help of microorganisms in their digestive tracts. Tapeworms could not survive without a host to live in. *Desmodium* could not disperse its seeds without the help of furbearers and humans. These examples show that mutualism, parasitism and some kinds of commensalism are all types of symbiosis. Table 4.1 summarizes the types of interactions we've explored in this chapter.

Interactions maintain balance within ecosystems.

Are interactions important? Yes. To prove it, let's remove a few examples of mutualism from the biosphere and see what happens. Without microorganisms to break down cellulose, most herbivores would soon die of malnourishment. This would hardly matter, though, because without fungi to help gather nutrients, nearly 90 percent of all plants on earth would die. With herbivores gone, the predators that eat them couldn't find enough food. Without flowering plants, pollinators such as hummingbirds, honeybees and butterflies would die. With many food supplies gone, humans would soon perish, too. The loss of mutualistic relationships would ripple through the biosphere until very few organisms remained. From this we can see just how important mutualistic interactions are.

Mink and muskrats provide another example of the importance of interactions. Mink are one of the primary predators of muskrats. If we were to compare the population sizes for mink and muskrats



The interactions between mink (left) and the muskrats they prey upon help maintain balance in wetland ecosystems.

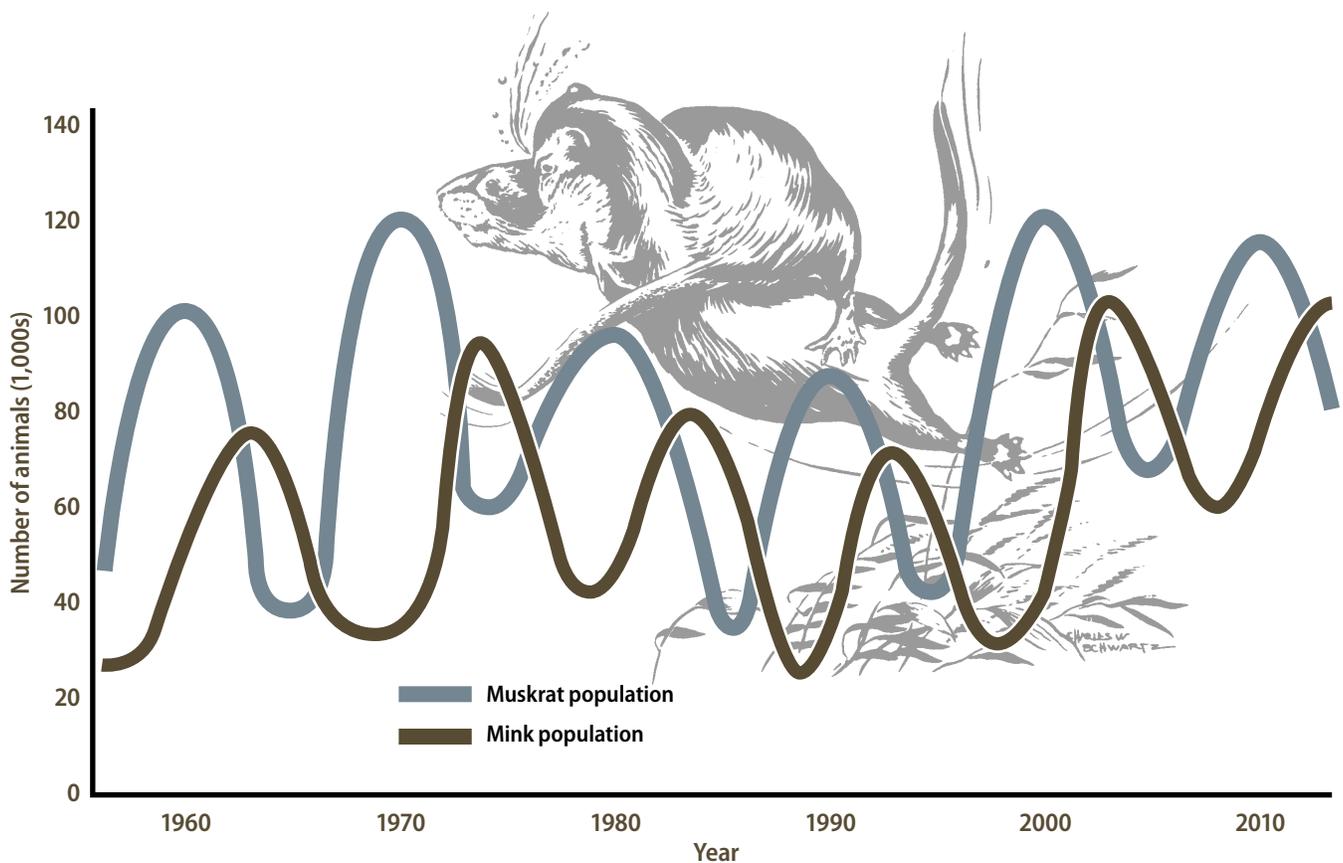


Figure 4.4—The peaks and valleys in the size of a mink population are influenced by the shortage or abundance of their prey, muskrats. Likewise, the peaks and valleys in a muskrat population are influenced by the abundance of mink. This pattern is typical of many predator-prey cycles.

(Figure 4.4), we would notice something interesting. About every 10 years the muskrat population reaches a peak, but then quickly plummets. Likewise, the mink population seems to grow and shrink on the same 10-year cycle, with one key difference: the mink population peaks and plummets about three years after the muskrat population. Why? When there are few mink, the muskrat population grows quickly. With more muskrats to eat, the mink population also begins to grow. Eventually the mink population begins to consume muskrats faster than the muskrat population can reproduce, and the muskrat population quickly shrinks. Without enough muskrats to eat, the mink population soon declines. This sequence results in a series of peaks and valleys in the population sizes of both mink and muskrats. Ecologists call these population fluctuations **predator-prey cycles**.

Predator-prey cycles affect more than just the organisms directly involved. Muskrats use aquatic vegetation for food and to build their lodges. Too many muskrats can consume all the vegetation in a marsh. While this is terrible for the cattails, bulrushes and arrowhead plants, it's equally bad for the marsh wrens that nest in cattails, the waterfowl that eat seeds produced by the plants, and the entire community of wetland organisms that depend upon marsh plants for food or shelter. Many of the organisms that eat plants are prey for other species. When prey disappears, predators soon decline. By keeping prey populations in check, predators help maintain balance in an ecosystem. ▲



Huge flocks of Carolina parakeets were a common sight when Lewis and Clark passed through Missouri in the early 1800s. By 1914, the colorful bird had been pushed to extinction by loss of habitat and unregulated hunting.