BIG IDEAS:

- Ecologists measure populations in different ways.
- Births and deaths cause populations to grow and shrink.
- With abundant resources, populations can grow quickly.
- Many factors limit how large a population can grow.
- Some limiting factors affect growth regardless of the population's density; other limiting factors affect growth in relation to the population's density.
- Population growth slows as population size nears carrying capacity.

POPULATION checks AND balances

A crowd of elementary students waits along the muddy bank of a creek. A Conservation Department pickup pulls up, and two biologists get out. Wearing thick leather gloves, the biologists unload a wire cage and carry it down the bank to the water's edge. Following the advice of the biologists, teachers warn students to keep their fingers away from the cage. The kids wear t-shirts that read, "Bring 'Em Back to Missouri."

This will be the students' first glimpse of an animal long absent from Missouri—the river otter. Early in our state's history, habitat destruction and unregulated trapping nearly wiped out Missouri's otters. A 1936 survey found only a handful of otters surviving in the swamps of southeastern Missouri's Bootheel. In the early 1980s, the Conservation Department started a stocking program to restore otters to their former habitat. The otters in the cage are part of this program.

When the otters poke their whiskered faces out of the cage, the children cheer. Giving little grunts and chuckles, the otters slip out and shuffle toward the creek. Hunch-backed and clumsy-looking on land, once they hit water they move with the sinuous grace of ballet dancers. For a few minutes the otters put on a show, swimming and diving exuberantly, obviously happy to be free of the cage. Then, one-by-one, the otters submerge and disappear, leaving a trail of bubbles in their wake.

Since those first releases in the 1980s, Missouri's otter population has soared from 70 to more than 15,000. River otters now flourish in nearly every aquatic nook and cranny of the state. Otters have made their way to places ecologists never imaged they could—sometimes to places where they aren't wanted. Otters eat fish. Fifteen-thousand otters eat tons of fish. This has caused conflicts between anglers and the newly established otter populations.

How did Missouri go from otterless to otterful in such a short time? What can be done to curb the growth of Missouri's otter population? In this chapter we'll learn how ecologists study populations, explore how populations grow, and examine the factors that limit population size.

Ecologists measure populations in different ways.

Recall from Chapter 1 that a population is a group of the same species living together in the same place at the same time. The boundaries of a population can be defined by the species' geographic range, by a natural barrier, such as a mountain range, or by an artificial barrier, such as the boundaries of a conservation area, set up by an ecologist studying the population *(Figure 3.1)*. We might study a population of otters living in the Grand River or a population of termites living in a rotting log.

Several things link members of a population to each other. Individuals in a population rely on the same resources for energy, water, shelter and space. They interact with each other on a regular basis. Most importantly for population growth, members of a population can mate with each other and produce offspring.

Understanding populations is important for many reasons. Ecologists study populations to:

- Predict how a population might react to a change in its environment
- Understand what causes a population to grow or shrink
- Figure out how much space a population needs to stay healthy
- Predict how many individuals to release into a new area to ensure the population persists
- Determine what kinds of resources could save an endangered species from extinction
- Decide how many individuals could be harvested from a game population without causing it to decline
- Learn how to control populations of crop pests, weeds, parasites and diseases

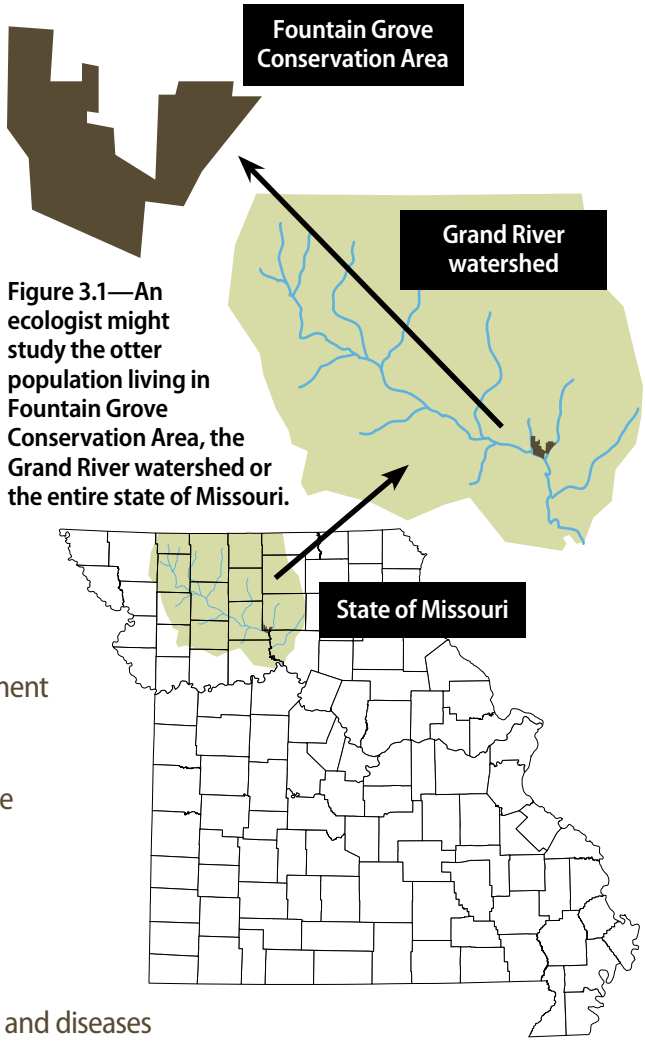

Figure 3.1—An ecologist might study the otter population living in Fountain Grove Conservation Area, the Grand River watershed or the entire state of Missouri.

When you go to the doctor, a nurse records your temperature, blood pressure, pulse and weight. These measurements—called vital signs—give the doctor clues to your overall health and how your body is functioning. In a similar fashion, ecologists learn a lot about a population by gathering a few key measurements.

One of those measurements is **population size**, or the total number of individuals making up the population. Ecologists usually represent population size with an uppercase N. N = 200 means that the population consists of 200 individuals. Population size rarely stays the same for long. Usually, it fluctuates as individuals die of old age, get eaten by predators, give birth to offspring or migrate into or out of the population.

Another important measurement is population density. **Population density** is the number of individuals per unit of area. To calculate density, you divide a population's size by the area it occupies. One river otter per square kilometer, 200 white oaks per hectare and 50 termites per square meter are all examples of population density. In general, larger organisms have lower population densities. This makes sense because larger organisms usually need more space and other resources to survive. For any population, densities will be higher when resources are plentiful and lower when resources are scarce.

Dispersion describes the spacing of individuals in the population in relation to each other. Populations can be dispersed in a clumped, uniform or random pattern *(Figure 3.2)*. In clumped dispersions, individuals are grouped in tight clusters. In uniform dispersions, individuals are spaced even distances from each other. In random dispersions, individuals can be found anywhere within an area.

For many populations, the pattern of dispersion is related to the arrangement of resources in a given area. If food, nesting sites, sunlight or other resources are distributed in patches across the landscape, the population will likely have a clumped pattern of dispersion. River otters are aquatic organisms, so you would expect to

Using Mark-Recapture to Estimate Population Size

For animals that are elusive or scattered throughout an area, ecologists use **mark-recapture methods** to estimate population size. Mark-recapture involves catching a sample of the population and marking the captured individuals with paint, a leg band, an ear tag or in some other way. After being marked, the individuals are released and allowed to mix back into the population. After time has passed, a second sample of individuals is captured. By comparing the number of individuals marked in the first sample to the number that have marks in the second sample, ecologists can estimate the total population size. The **Lincoln-Petersen estimate** is a simple and widely used method of mark-recapture sampling. Here's the formula:


A researcher marks a female cardinal with a metal leg band.

$$N = \frac{n_1 n_2}{m_2}$$

N = population size
n_1 = the number of individuals marked and released in the first sample
n_2 = the total number of individuals captured in the second sample
m_2 = the number of individuals with marks in the second sample

Let's say we are trying to estimate the population size of the cockroaches living in your garage. One night we go to your garage, capture 32 roaches and paint little white marks on their backs. A week later we go back and capture 44 roaches. We note that 15 roaches in our second sample have white marks from the previous sample. Let's plug these numbers into our equation:

$$N = \frac{(32)(44)}{15} \quad \textit{becomes} \quad N = \frac{1{,}408}{15} \quad \textit{which means} \quad N = 94$$

From this calculation, we can estimate that about 94 cockroaches live in your garage. Yuck! Ecologists use the Lincoln-Petersen method to estimate the population size of everything from box turtles to bluegill to bluebirds. While it is effective, this method assumes:

- Between the two samples, the population has no births, deaths, immigration or emigration.
- All individuals have the same probability of being caught.
- Marking does not affect survival.
- Marking does not affect the likelihood that an individual will be recaptured.
- Marked individuals do not lose their marks between captures.

If any of these assumptions prove false, the accuracy of the Lincoln-Petersen estimate decreases.

find individuals in an otter population clustered near water. When resources are uniformly distributed across the landscape, the population is more likely to show a random or uniform pattern of dispersion. If growing conditions were similar throughout a prairie, you would expect to find a population of Indian grass dispersed in a uniform pattern across the landscape.

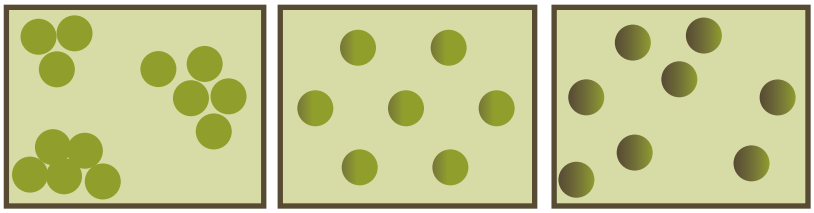

Figure 3.2—Types of Dispersion

Sampling Populations

How many otters live in a watershed? How many white oaks live in a forest? How many bluegill live in a pond? To determine population size, ecologists use censuses and samples. Some organisms are easy to count. Although it might take time, you could easily count every white oak in a 20-hectare forest. This **census**—a count of all the individuals in a population—would give you a precise measurement of that forest's white oak population.

But, what about populations scattered over an area of hundreds of square kilometers? Or populations of organisms that move around—like river otters or songbirds? What about populations that are difficult to see because they live underwater or underground, are microscopic or come out only at night? In each of these cases, ecologists use samples. In a **sample**, you count a small portion of the population and use it to estimate the entire population size. It's like guessing how many jellybeans are in a jar. If the jar is 20 centimeters tall, you might count the number of jellybeans in the first two centimeters of the jar (your sample) and multiply by 10 to estimate how many jellybeans are in the entire jar.

Samples can be obtained in many ways. Sometimes ecologists divide a large area into smaller sections called **quadrats** and count all the individuals in some of the quadrats. At other times, ecologists walk **transects**, straight lines of a known length, through an area and count the individuals they see. For elusive animals, ecologists can count nests, scat, hair or other evidence left behind. Here are a few ways Missouri ecologists obtain samples to estimate population sizes.

A hair snare snags a tuft of fur when animals brush against it.

Hair Snares for Black Bears

To figure out how many black bears live in Missouri, biologists use hair snares, a short piece of barbed wire that snags a tuft of fur when bears brush against it. By extracting DNA from the snared hair, researchers can learn the bear's sex, age and kinship to other bears. Because each bear's DNA is unique, hair samples can be used as genetic identification tags, allowing researchers to tell whether a specific sample is from a previously identified bear or a different one. This information will reveal important characteristics about Missouri's bear population, such as its size, ratio of males to females, travel patterns and genetic diversity.

The Shocking Truth About Counting Fish

Fisheries biologists sample populations using a variety of gear and techniques, few of which require SCUBA tanks and swim fins. In fact, a fisheries biologist wouldn't want to dip a single toe in the water when using

The interactions that take place among members of the population also affect dispersion. If individuals are attracted to each other, the population tends to have a clumped pattern of dispersion. In winter, bobwhite quail are attracted to each other to keep warm. Gathering in groups—called coveys—leads to quail populations having a clumped dispersion in winter. When individuals in a population are repelled by each other—like during summer when bobwhite males chase other males out of their territory—the population usually has a uniform pattern of dispersion. If individuals ignore each other, the population tends to have a random pattern of dispersion.

one of the most common sampling techniques—electrofishing. Electrofishing gear pumps electrical current into the water. This stuns nearby fish that float to the surface where biologists capture them with long dip nets. After recording information about each fish, such as its species, sex, length and weight, the fish is returned to the water unharmed. From this information, biologists learn what species of fish live in a body of water and estimate each species' population size, sex ratio and other important population characteristics.

Electrofishing is one method biologists use to sample fish populations.

The Plane Truth About Counting Ducks

Never bet against a waterfowl biologist in a game of guessing how many jelly beans are in a jar. Why? Because waterfowl biologists count thousands of ducks each fall and spring—from an airplane, 400 feet in the air, flying at 100 miles per hour. As they zip over a large concentration of ducks, the biologist divides it into smaller segments of similar densities, say a 1,000 ducks each. When the birds are spread out, it may take a fairly large area to equal 1,000 ducks. When it's cold, 1,000 ducks might be packed together in a relatively small space. The biologist then counts the total number of segments and multiplies by 1,000 to get an estimate of the total number of ducks. After estimating the total number of ducks, the biologist makes another, much lower pass in the airplane. This time, the biologist tries to figure out the percentage of mallards, pintails and other ducks making up the concentration. In this way, biologists learn how many and what kinds of ducks use Missouri's wetlands during the fall and spring migrations.

Waterfowl biologists use aircraft to count ducks and geese.

It's a Dirty Job, But Someone's Got to Do It

Scouring a river for otter scat isn't the most glamourous job in the world, but it does help biologists estimate otter numbers. Researchers are working to determine if a relationship exists between how much scat they find along a river and the number of otters that live there. If a relationship exists, biologists will have an inexpensive and easy way to estimate otter abundance. In addition, researchers are testing whether DNA can be extracted from the scat. If so, it could be used to give each otter a unique genetic identity, allowing researchers to learn about an otter population's travel patterns, sex ratio and genetic diversity.

Researchers count otter scat to estimate population size.

Births and deaths cause populations to grow and shrink.

Populations are dynamic, continually growing and shrinking over time. In 1980, we had about 70 river otters in Missouri. By 2000, the population had skyrocketed to over 15,000. In 2007, the population had decreased to about 10,000 individuals. What caused this fluctuation? The same thing that causes all populations to fluctuate over time—births, deaths, immigration and emigration *(Figure 3.3)*.

Births and **immigration** (moving into an area) add to population size. Over an 11-year period, the Conservation Department took 845 otters from the swamps of Louisiana and released them into the streams and wetlands of Missouri. This immigration of otters caused the population size to increase. Once the otters were here, they started reproducing at incredibly high rates. Although litters of two or three pups are typical in other populations, in Missouri, female otters gave birth to three or four pups each spring. The high number of births contributed to fast population growth.

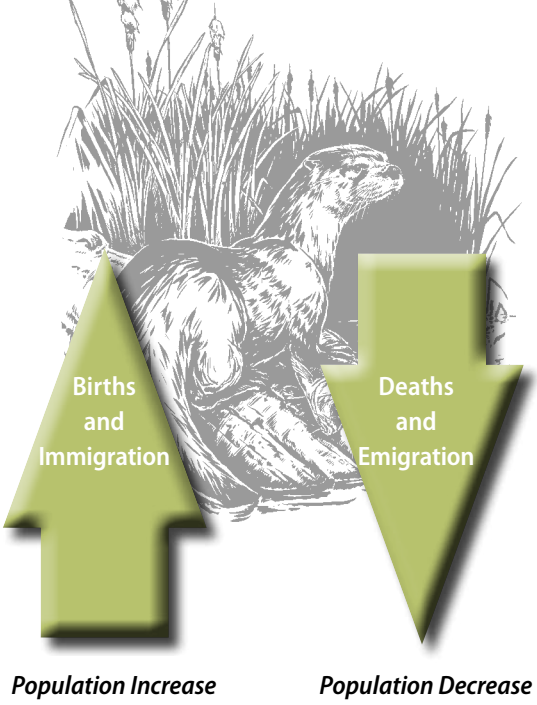

Figure 3.3—What affects population size?

Deaths and **emigration** (moving out of an area) subtract from population size. Due to an abundance of habitat and food, few otters moved out of Missouri. Because otters have few natural predators, there were also few deaths. As otters multiplied and began moving into fishing ponds and streams, phone calls from angry anglers began pouring in to Conservation Department offices. Something had to be done to put the brakes on the out-of-control otter population. In 1996, the Conservation Department started an otter-trapping season. Over the next decade, trapping helped bring Missouri's otter population down to a level that was better for fish populations and people.

For most populations, births and deaths affect population size more than immigration and emigration. When there are more total births than deaths, the population grows. And, when there are more total deaths than births, the population shrinks.

With abundant resources, populations can grow quickly.

William Shakespeare must have been a bird lover. In his plays and poems he wrote about all kinds of birds, from ravens to peacocks to nightingales. What does Shakespeare have to do with ecology? In 1890 and 1891, the American Acclimation Society, a group hoping to introduce every bird in Shakespeare's plays to the United States, released 160 European starlings into New York's Central Park. Since that time, the starling population has skyrocketed. Starlings are now one of the most abundant birds, not only in Missouri, but throughout North America. Their population of 200 million stretches from one coast to the other, each bird a direct descendent of the original 160 released in Central Park.

The European starling population grew from 160 birds to more than 200 million in just over a century.

We've seen how Missouri's otter population went from 70 to 15,000 in just a few years. We've learned how North America's starling population went from 160 to 200 million in just over a century. What does this tell us about the ability for populations to grow? It tells us that regardless of the population—whether it is starlings, otters or human beings—the pattern of growth is always the same.

With abundant resources—food, space, nesting sites—populations grow slowly at first and then faster and faster as time

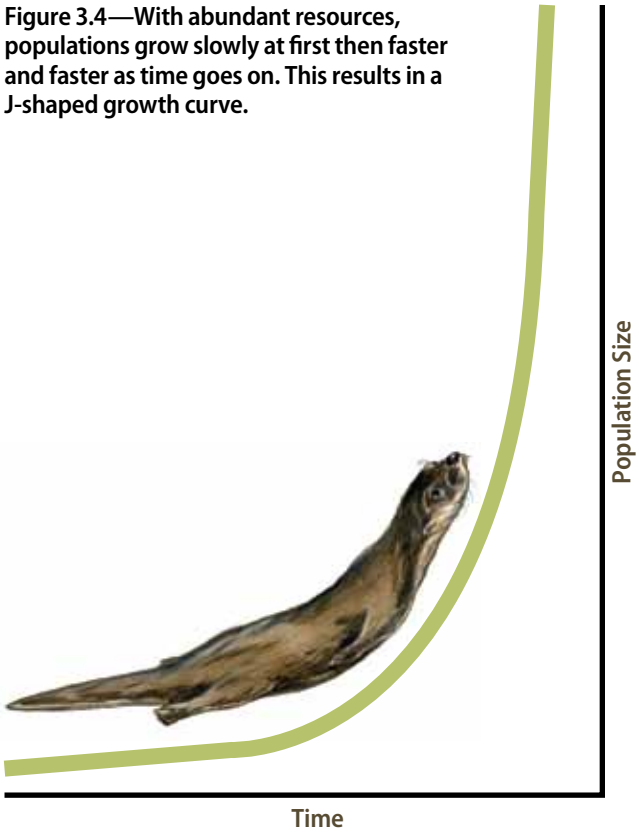

Figure 3.4—With abundant resources, populations grow slowly at first then faster and faster as time goes on. This results in a J-shaped growth curve.

goes on. If we were to use a graph to plot this kind of growth over time, it would give us a J-shaped curve like the one shown in Figure 3.4.

What causes this pattern of growth? Reproduction. Parents in each population have offspring. Eventually these offspring grow up, reach reproductive age, and have offspring themselves. This causes the population to increase by multiplication rather than addition. This type of growth, when a population increases in proportion to its size, is called **exponential growth**.

Exponential growth is characteristic of populations rebounding from a catastrophe, like a population of bass left alone after years of overfishing or a population of oak trees recovering from a wildfire. Exponential growth is also typical of populations newly introduced into a favorable environment—like Missouri's river otters, European starlings in North America or an outbreak of insect pests in your vegetable garden. Some populations, such as the human population, grow continuously because babies are added to the population at all times of the year. Other populations, such as river otters,

Additive Growth vs. Exponential Growth

To illustrate the difference between exponential growth and growth from addition, let's consider a riddle. Say I hired you to be an ecologist for the Conservation Department. I offer you two different options for getting paid. In the first option, you start off making a dollar, but I add a dollar to your salary each week. In the second option, you start off making a penny, but I double your salary each week. Which is the better offer? Let's use a table to figure it out.

Week	Salary Option 1	Salary Option 2
1	$1	1¢
2	$2	2¢
3	$3	4¢
4	$4	8¢
5	$5	16¢
6	$6	32¢
7	$7	64¢
8	$8	$1.28
9	$9	$2.56
10	$10	$5.12
11	$11	$10.24
12	$12	$20.48
13	$13	$40.96
14	$14	$81.92
15	$15	$163.84

As you probably guessed, the second offer is the better deal. This is because in the second option your salary grows by multiplication rather than addition. As you can see from the table, your salary starts off growing slowly, but quickly picks up. By the twenty-eighth week, you would be making over one million dollars! This shows the power of exponential growth.

add offspring to the population at certain times of the year, usually when resources are most abundant. Regardless of whether the growth is continuous or in spurts, with abundant resources, all populations have the capability to grow exponentially.

To figure out how quickly a population might grow over time, ecologists need to figure out the rate at which the population is multiplying. By comparing birth and death rates over a set period of time, ecologists can determine how much a population is increasing or decreasing on a per individual basis. Ecologists call this the **per capita rate of growth**. If they know the per capita rate of growth and they know how many individuals make up the population, it's relatively easy to estimate how the population's size might change over time. For example, during the 1990s, Missouri's river otter population had a per capita growth rate of about 1.28. This means that each spring, each otter contributed 1.28 offspring to the population. In 1993, there were about 2,500 otters making up Missouri's population. What would the population size be in 1994? A simple formula will help us get the answer:

population size in one year = current population size X per capita growth rate

An ecologist would use symbols to write the same equation:

$N_{t+1} = N_t\lambda$

N_{t+1} = Population size at one year in the future (t + 1 means "time plus one")
N_t = Population size right now
λ = Per capita growth rate

If we put numbers into the equation we get:

$N_{t+1} = 2{,}500(1.28)$
$N_{t+1} = 3{,}200$

If we wanted to estimate the population's size at three years in the future, we could perform this calculation three times. Or, we could use this equation, which does the same thing:

$N_t = N_0\lambda^t$

Here, N_t stands for population size at t years in the future. N_0 stand for the population size you start out with. So, if we wanted to figure out the size of Missouri's otter population at three years in the future, we would plug numbers into the equation like this:

$N_3 = 2{,}500(1.28^3)$
$N_3 = 2{,}500(2.10)$
$N_3 = 5{,}250$

This method of estimating a population's growth rate assumes that each member of the population has the same chance of giving birth or dying as any other member of the population. Of course, this isn't often the case. Usually birth and death rates vary with the ages of individuals in the population. When this is true, the per capita rate of growth must be calculated for each age class of the population. To do this, ecologists use a sort of spreadsheet called a **life table**. Life tables provide a more accurate estimate of how populations might change over time.

Predators, such as coyotes, are a limiting factor for prey populations. A shortage of prey, such as rabbits, acts as a limiting factor for predator populations.

Many factors limit how large a population can grow.

Over time, exponential growth can lead to staggering numbers. If Missouri's river otter population was allowed to grow unchecked, in just over a century there would be nearly 9 *quadrillion* otters—9,000,000,000,000,000—enough to completely cover the face of the earth!

Obviously, this could never happen. As the population grew, competition for food, water, space, den sites and other resources would become fierce. With each otter getting a smaller and smaller share of resources, eventually, some of the otters would die. Poor nutrition would lead to lower birth rates. Offspring would die of malnourishment. As the population became more crowded, it would become easier for diseases and parasites to spread from one otter to another. These factors that slow a population's growth or prevent it from existing in certain areas are called **limiting factors**.

Many things can act as limiting factors. Some limiting factors are abiotic. Sunlight, precipitation, the amount of nutrients in the soil or the amount of oxygen dissolved in water are limiting factors for many populations. Temperature also is an important abiotic limiting factor. Instead of a thick coat of fur, armadillos are covered in hard, bony plates. These plates protect them from predators, but the lack of fur makes armadillos prone to frostbite and freezing to death in cold weather. For armadillos, cold temperatures have kept their population from growing and expanding into northern Missouri.

Some limiting factors are biotic. We learned that trapping is an important limiting factor for Missouri's river otter population. For a population of smallmouth bass, otters—which prey upon bass—are a limiting factor. From these two examples, we might guess that predation—whether from humans or other organisms—is a major limiting factor for many populations. Sometimes competition with other organisms is a limiting factor. Bur oak seedlings compete with other trees for sunlight, water and nutrients. Songbirds may compete for nesting sites. The availability of food, a shortage of mates, an outbreak of disease, an infestation of parasites—all of these can be limiting factors.

Limiting factors slow population growth by affecting birth and death rates. When there are few limiting factors, births increase and deaths decrease. When there are many limiting factors, births decrease and deaths increase. In the case of river otters, trapping increased death rates, lowering the population's size. This led to fewer otters reproducing, so births also decreased. The opposite happened with fish populations. With fewer otters, fish deaths decreased and births increased. This caused fish populations to rebound.

Some limiting factors affect growth regardless of the population's density; other limiting factors affect growth in relation to the population's density.


A fish kill from a toxin is an example of a density-independent limiting factor.

Some limiting factors affect a population regardless of the population's density. Consider what an ice storm might do to an armadillo population, what a drought might do to a population of water-loving plants, or what a toxin spilled into a stream might do to a fish population. In each of these cases, the limiting factor causes the population to decrease regardless of how densely crowded the population is. Limiting factors that affect a population regardless of its density are called **density-independent factors**.

Other limiting factors affect a population in relation to the population's density. Consider the probability that a deadly disease could be transmitted from one member of a population to another. If members of the population are spaced far apart, the probability of transmission is low. However, if members of the population are spaced close together, the probability of transmission is higher. Limiting factors that affect a population in ways related to the population's density are called **density-dependent factors**.

To illustrate how density-dependent factors affect population growth, let's consider a coyote population and one of its limiting factors, the availability of rabbits to eat *(Figure 3.5)*. When the coyote population's density is low—about 0.2 coyotes for each square kilometer—each coyote gets a larger share of rabbits to eat. Because of this, survival rates are higher. Higher survival rates plus better nutrition leads to birth rates of 7-9 pups in each litter, and the coyote population grows. When the coyote population's density is higher—about 2 coyotes per square kilometer—the number of rabbits in the area is divided among more coyotes. This means that each coyote gets fewer rabbits to eat. If more coyotes compete for the same number of rabbits, it's likely that some of the coyotes will starve. With low survival and poor nutrition, birth rates decrease to about 4 pups in each litter. When this happens, the coyote population will stop growing, and perhaps even decrease in size. What we learn from this example is that density-dependent factors are important regulators of population size.

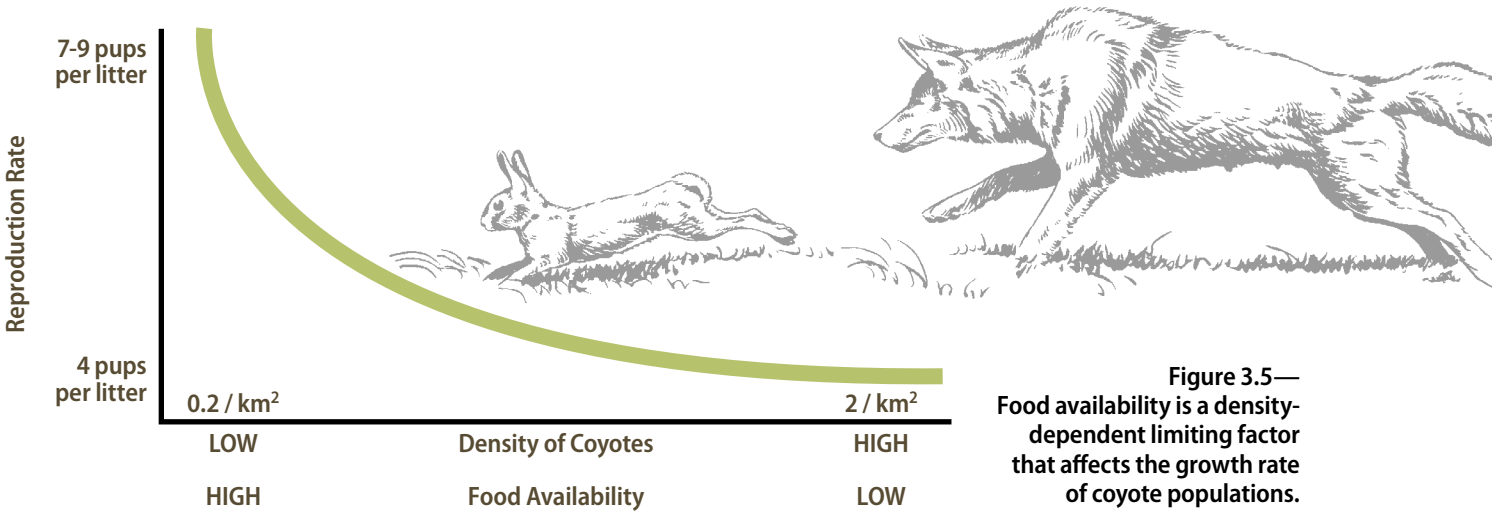

Figure 3.5—Food availability is a density-dependent limiting factor that affects the growth rate of coyote populations.

Births, Deaths and Hunting

Deer, turkeys, ducks and many other animal populations are hunted for food, clothing and sport. Rule makers consider social, economic and ecological factors when setting hunting seasons, bag limits and harvest methods for these populations. Wildlife biologists, using what they know about how populations grow and change, provide valuable scientific input to the rule makers.

Wildlife biologists often represent population change with a simple formula:

population change = (births + immigration) - (deaths + emigration)

According to this formula, if we have a population of 8.5 million mallards, and hunters kill 10,000 on the opening day of duck season, on the second day of hunting season there will be 10,000 fewer mallards. The formula works well in the short term. However, if we try to predict the mallard population a year into the future, the math gets a little fuzzy. This is because the four variables on the right side of the equation—births, deaths, immigration and emigration—are not independent, but affect each other. A decline of 10,000 ducks might lead to a drop in the population's size next fall, but it might also cause mallard numbers to increase. How can this be? The answer has something to do with **compensatory mortality**.

Consider a mallard population in which winter food is a limiting factor. With a large population, there isn't enough food to go around, and 10,000 ducks die each year of starvation. If hunters kill a percentage of the population, there is more food available to the surviving mallards, and fewer ducks starve. In this example, the number of mallards that die will be the same regardless of whether hunting or starvation is responsible. Thus, if hunters kill 6,000 ducks, 4,000 will die from starvation, and if hunters kill 8,000 ducks, 2,000 will die from starvation. This is called compensatory mortality because different causes of death balance out or *compensate* for each other. **Additive mortality** occurs when different causes of death add to each other. When additive mortality occurs, if hunters kill 5,000 ducks, it would add to the 10,000 that normally die of starvation. Thus, the population would decrease by 15,000 ducks.

Although there is considerable debate among biologists about whether hunting is additive or compensatory, for most species, hunting seems to be compensatory up to a point. Setting harvest limits below this point allows hunters to take a percentage of the population without causing long-term declines. However, if individuals are harvested beyond this point, hunting becomes additive, and the population does not rebound to its former size over the next breeding season. Without correction, additive mortality can cause the population to decline or even disappear—something wildlife managers strive to avoid.

For most species, including waterfowl, hunting seems to be compensatory up to a point.

Population growth slows as population size nears carrying capacity.

Because of limiting factors, populations do not grow exponentially for very long. As with the coyote population, competition for scarce resources lowers birth rates and increases death rates. This causes exponential growth to slow down and level off. If we plotted this leveling off on a graph, it would form an S-shaped growth curve like the one shown in Figure 3.6.

When a population's growth reaches the point where it levels off, we say the population has reached its carrying capacity. **Carrying capacity** is the number of individuals a given area can support at a given time. Ecologists often use K to represent carrying capacity. Resource managers use the concept of carrying capacity to estimate how much habitat must be conserved to maintain healthy populations of plants, animals and other organisms.

After an initial burst of population growth, the size of most populations hovers around carrying capacity. At carrying capacity, the number of offspring born equals the number of individuals that die. When a population's size grows larger than carrying capacity, there aren't enough resources to go around. There are more deaths in the population than births, and this brings the population size back toward carrying capacity. When a population's size is less than carrying capacity, there are more than enough resources to go around. There tend to be more births than deaths, and this also brings the population size closer to carrying capacity.

Carrying capacity isn't a fixed amount, though. Resources can become more abundant or scarce, and limiting factors can increase or decrease over time. If you planted a larger garden, you would increase the resources—food and space—available to a population of insect pests living there. Because of this, the carrying capacity for your garden would increase, and there would be more insects. Although Missouri's otter population is close to carrying capacity right now, if more wetland habitat was created or if the Conservation Department closed the trapping season, we would expect the state's carrying capacity for otters to increase.

Sometimes, populations reach sizes humans can't tolerate before they reach carrying capacity. River otters in Ozark streams, Canada geese on a golf course, white-tailed deer in a city, weeds in a soybean field, *Streptococcal* bacteria (which cause strep throat) in a biology classroom—these are all populations we try to keep below carrying capacity. Your vegetable garden could probably support a much larger population of insect pests than you will tolerate. To keep pest populations low, you might release lady beetles to eat the pests, spray soap to make the vegetables inedible to insects or use pesticides. When populations begin to grow higher than humans can tolerate, resource managers use similar methods to bring the populations back under control. There are many ways to do this. For example, resource managers can open hunting or fishing seasons and set harvest limits to keep game populations healthy and at levels that reduce conflicts with the human population. Managers also can keep populations low by managing habitat. When Canada goose populations get too big in a park or on a golf course, managers can let shoreline vegetation grow tall to make the habitat less appealing to geese. ▲

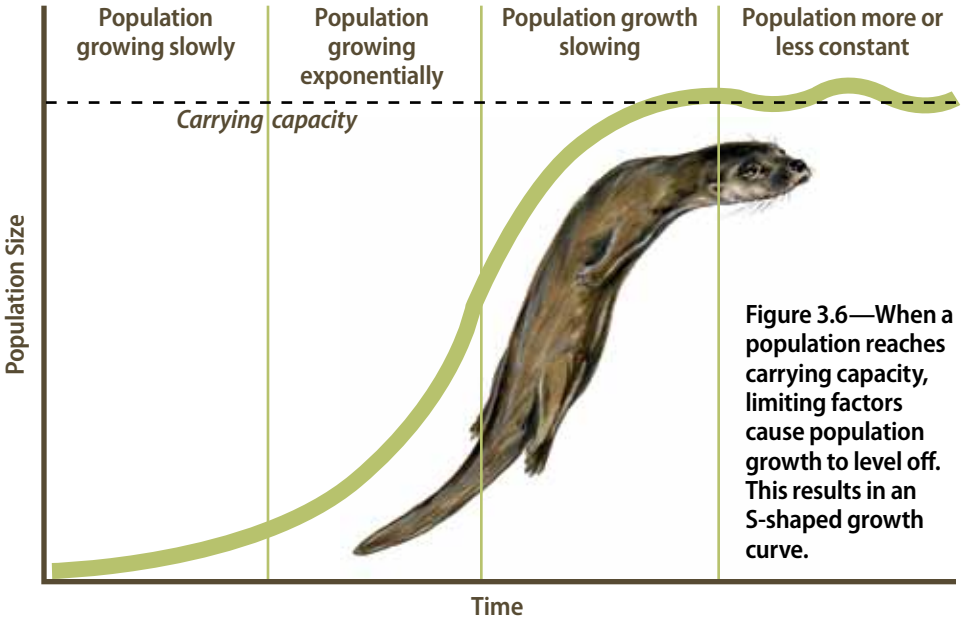

Figure 3.6—When a population reaches carrying capacity, limiting factors cause population growth to level off. This results in an S-shaped growth curve.

Keeping Missouri's Deer Under Cultural Carrying Capacity

Every day, Conservation Department managers are asked: "Why don't you do something about the deer herd?"

Some people ask this question believing there aren't enough deer. They want to know what's being done to increase deer numbers. Others believe there are too many deer and want to know what's being done to reduce deer numbers. Resource managers are constantly trying to find a balance between one person's "too many" and the next person's "not enough."

Missouri's white-tailed deer population illustrates the difference between biological carrying capacity and **cultural carrying capacity**. Although Missouri is currently home to over a million deer, the biological carrying capacity—the number of deer that the habitat can support—has not yet been reached. However, the cultural carrying capacity—the number of deer that people will tolerate—has generally been reached, and in some areas, exceeded.

What are the consequences of high deer numbers? Although rare in Missouri, deer can overbrowse forests which eliminates understory plants and creates long-term changes in forest communities. Damage to agricultural crops, fruit orchards, commercial nurseries and Christmas tree farms can inflict significant financial losses on farmers and nursery owners. Residents in urban and suburban areas can experience damage to vegetable and flower gardens. And, anyone who drives seems concerned about deer-caused vehicle accidents.

Whether a deer population increases, decreases or remains stable depends upon the balance between births and deaths. Birth rates for Missouri deer are high, with most 2-year-old does producing twin fawns and 10 to 15 percent producing triplets. In northern Missouri, where birth rates are highest, about 35 percent of 1-year-old does produce a fawn.

Studies show that death rates for fawns during their first 6 months of life may exceed 40 percent. Without hunting, though, death rates for older deer are less than 5 percent. With few natural predators remaining, hunting has become the leading cause of deer deaths in most of Missouri. Each year hunters take 40 to 70 percent of the antlered bucks and up to 25 percent of the does. This indicates that hunting is an important tool that resource managers can use to control deer numbers.

Not all hunters affect deer populations the same, however. Hunters who shoot only bucks have less of an impact on deer populations than hunters who shoot only does. Since one buck can mate with many does, males can remain at much lower numbers than does without affecting the population's overall birth rate. Indeed, population models show that harvests of up to 80 percent of the bucks from a herd have little effect on the overall population growth. Similar harvest of does, however, has a substantial effect on slowing population growth.

It makes sense, then, that to maintain deer numbers at cultural carrying capacity or lower deer numbers in areas where cultural carrying capacity is exceeded, the Conservation Department has regulations to encourage the harvest of does. During the November portion of the firearms deer season, hunters can harvest only one antlered deer. However, in the northern half of the state, where deer densities are highest, hunters—with the right permits—also can harvest an unlimited number of does. In addition, in the northern two-thirds of the state any antlered deer a hunter harvests must have at least four antler points on one side of its rack. The objective here is to restrict the number of bucks that can be taken, thereby increasing the likelihood hunters will harvest does. A benefit of this regulation is that it allows more bucks to attain older age and larger antlers—something many hunters would like to see.


Hunting is an important tool that resource managers use to control deer numbers.

A shorebird probes its bill in the muck of a mudflat to find aquatic invertebrates to eat. This connection—between a predator and its prey—is just one of countless interactions that occur in nature.