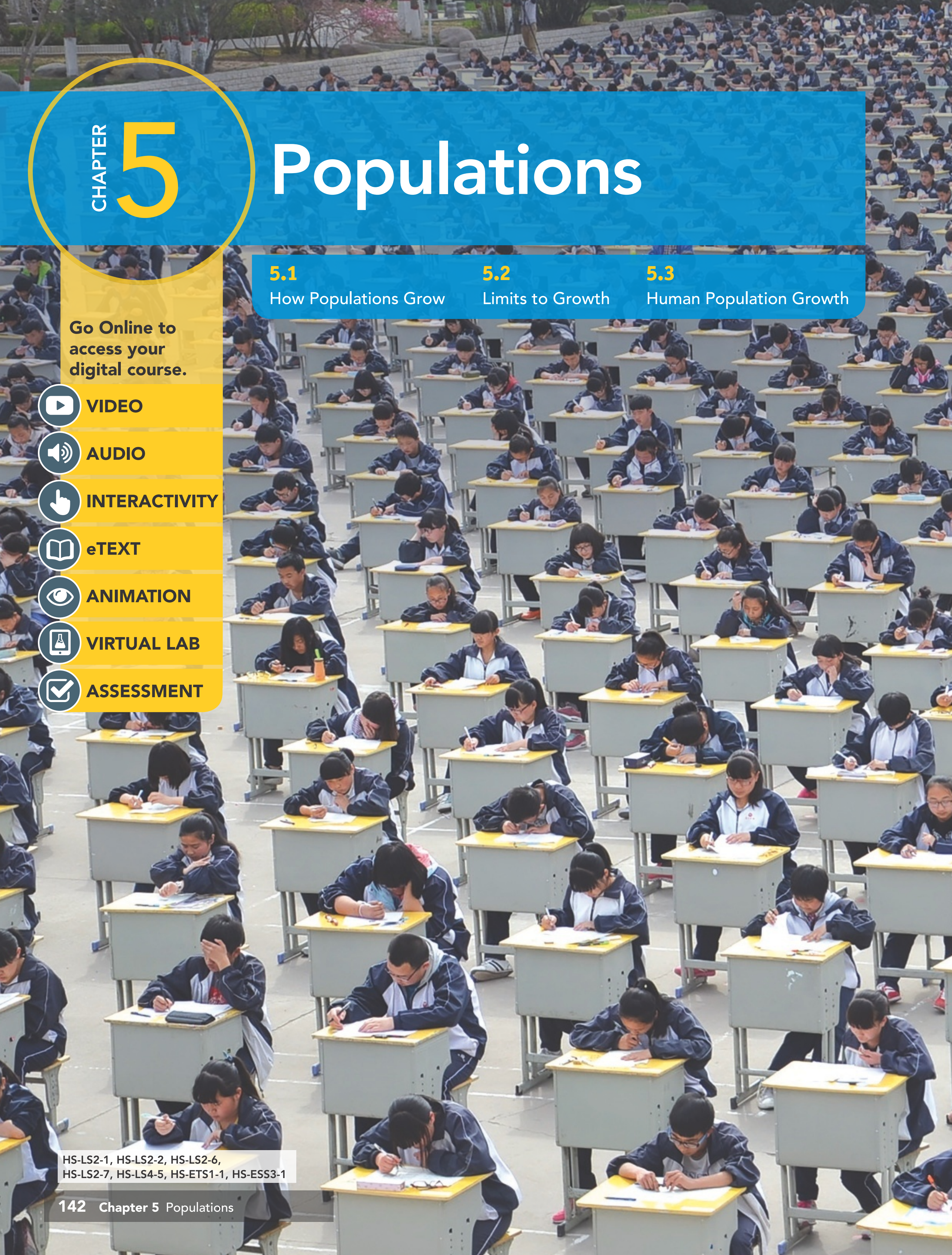


CHAPTER 5 Populations

Go Online to access your digital course.

- VIDEO
- AUDIO
- INTERACTIVITY
- eTEXT
- ANIMATION
- VIRTUAL LAB
- ASSESSMENT

HS-LS2-1, HS-LS2-2, HS-LS2-6, HS-LS2-7, HS-LS4-5, HS-ETS1-1, HS-ESS3-1

CASE STUDY

What can we learn from China?

China has had a sophisticated culture and a productive economy for much of its history. The country's abundant natural resources and use of technology have long supported a large, and growing, population. Between 1650 and 1800, China's population doubled from 150 million to 300 million. By the late 1800s, it reached 450 million … and the country started running out of farmland. By then, the government was struggling to cope with China's population explosion.

In the years since, China's population generally kept increasing despite many internal struggles, battles with Western powers, and civil war. One exception occurred between 1958 and 1962. China's leader, Mao Zedong, enforced a program of agricultural policies called "The Great Leap Forward." The result was one of the worst catastrophes in Chinese history. Farmers were not able to supply the food that the large population needed. As a result, as many as 45 million people died. To justify his approach, Mao made an extraordinary statement: "When there is not enough to eat, people starve to death. It is better to let half of the people die so that the other half can eat their fill."

But almost immediately after that disaster ended, population growth resumed. On average, Chinese women were bearing close to six children each. By 1970, China's population had grown to 790 million. The needs of that growing population caused serious social and ecological problems. In response, the government enacted a program to control population growth. They tried to encourage people to marry when they were older and have fewer children. The birthrate fell, but not far enough to meet the government's goals.

In 1979, the government set up a "one child" policy. It rewarded families that had only a single child with better access to schools, medical care, housing, and government jobs. Couples with more than one child were heavily fined. This policy has been reworked several times, and has had several unintended results. In 2005, there were 32 million more males under the age of 20 than females. (In traditional Chinese society, sons are preferred because they provide support for aging parents.)

In 2016, the government relaxed the policy and allowed families to have two children. Yet the one-child policy definitely slowed population growth, and it is still affecting the country. Today, most women have fewer than two children on average. This puts China in a better position as it tries to handle its major economic and environmental problems.

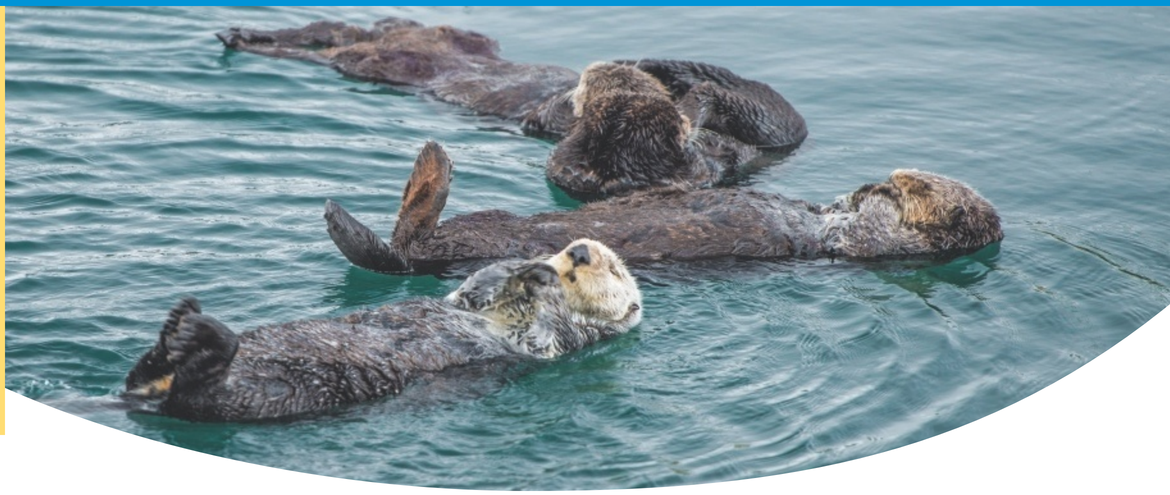
Many other countries, and the world as a whole, face the challenge of large and rapidly growing populations. Are there lessons to be learned from China's experience? What can we learn from nature that can help us understand human populations? How does the environment affect the growth of populations in general? How do populations affect their environment?

Throughout this chapter, look for connections to the CASE STUDY to help you answer these questions.

Students taking an exam in the Shaanxi province of China

LESSON 5.1

How Populations Grow



KEY QUESTIONS

- *How do ecologists study populations?*
- *What factors affect population growth?*
- *What happens during exponential growth?*
- *What happens during logistic growth?*

HS-LS2-1: Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
HS-LS2-2: Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

VOCABULARY
population density
population distribution
age structure
immigration
emigration
exponential growth
logistic growth
carrying capacity

READING TOOL

As you read this lesson, use the graphic organizer in your **Biology Foundations Workbook** to take notes on how both types of population growth occur.

Off the coast of California, southern sea otters are making a comeback. These mammals, along with the closely-related northern sea otters, once lived in an area that stretched from Baja California all the way up to Alaska. They were nearly wiped out by fur hunters during the eighteenth century. However, in 1911, otters were protected by international treaty, and their numbers began increasing. But southern sea otters are still endangered because they live only along a short stretch of the California coastline. A single large oil spill could wipe them out. Otters are important to the health of kelp forests because they feed on sea urchins and other invertebrates that eat the kelp. Without the otters, the kelp forests were disappearing.

Meanwhile, divers off the coast of North Carolina couldn't believe their eyes. They were certain they'd seen a lionfish. Why was that surprising? Because lionfish are native to the Pacific Ocean, not the East Coast of the United States! Recently, more and more lionfish have been reported around Florida, throughout the Caribbean, and all around the Gulf of Mexico, and they are still spreading. Fisheries and biologists are worried, because lionfish are predators that eat at least 70 species of native fishes. How did they get here? Why are their numbers increasing so rapidly? Can we control them?

Describing Populations

Imagine that you're investigating an aggressively spreading species like lionfish, or an endangered species like sea otters. Some of the first questions you ask might be "How many individuals of this species live here?" "Where else do they live?" or "Are those populations stable, increasing, or decreasing?" Welcome to population biology! ***Ecologists study populations by examining their geographic range, growth rate, density and distribution, and age structure.***

Source: U.S. Geological Survey Department of the Interior/USGS

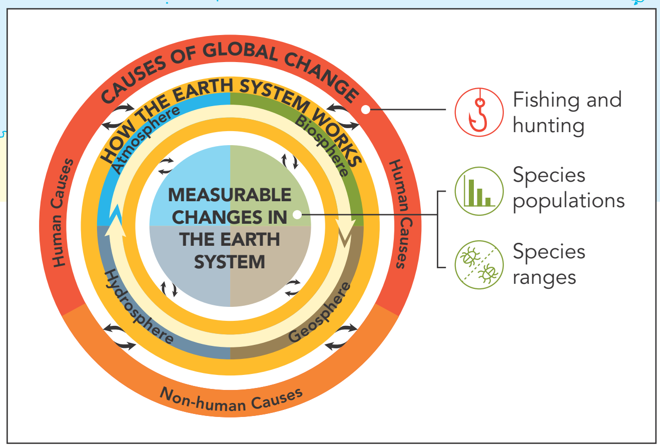


Figure 5-1

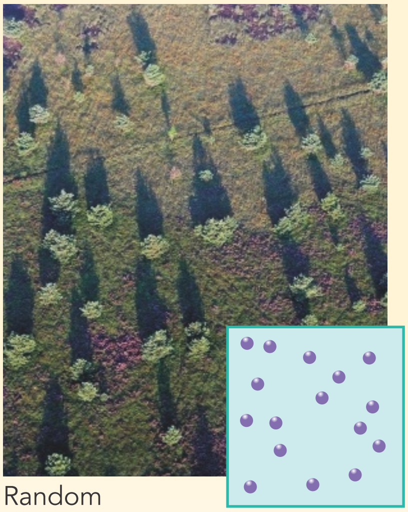
Geographic Range of Lionfish

The geographic range of the lionfish is increasing from the green areas in the Pacific and Indian Oceans, where it is native, to the Atlantic and Caribbean, where it is an introduced invasive species.

Geographic Range The places a population lives make up its geographic range. A population's range can vary enormously in size, depending on the species. For example, the range of a bacterial population in a rotting pumpkin is smaller than a cubic meter. The natural range of lionfish, on the other hand, stretches thousands of kilometers across the Pacific and Indian Oceans, as shown in **Figure 5-1**. The range of the invading lionfish population, shown in red, now stretches from as far north as Boston to at least as far south as Venezuela.

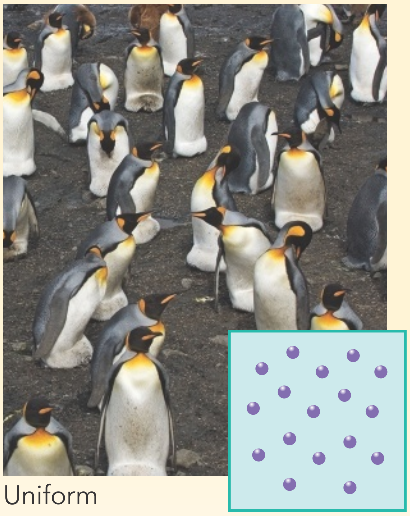
The range of sea otters, on the other hand, has been changing in the opposite direction, and for other reasons. Their range decreased during the time they were hunted, and has only partly recovered over the last century. Ranges of both northern and southern sea otters today are still only a fraction of the sizes they once were. Knowing an organism's range today, as well as its historic range, is important in understanding its relationships with other species in its habitat.

Growth Rate Will the size of a population stay the same, increase, or decrease? The answer to that question depends on the population's growth rate. Lionfish populations in their native habitats stay pretty much the same size over time, so their growth rate is about zero. By contrast, lionfish populations in the Atlantic, Caribbean, and Gulf of Mexico have very high growth rates, so those populations are increasing rapidly. Populations can also have negative growth rates, meaning that their numbers decrease. That was the case for otters in the Pacific before hunting was banned.



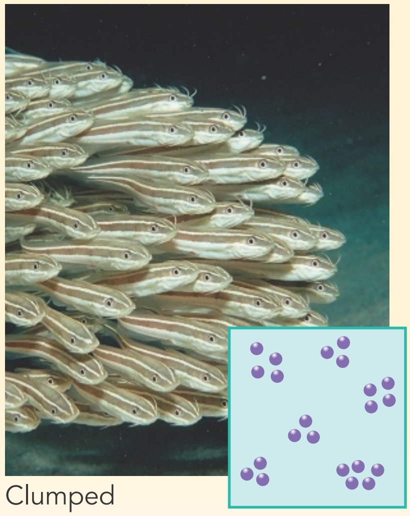
Random

In a random population, individuals are spaced unevenly. These trees shown a random population distribution.



Uniform

In a uniform population, such as this king penguin population, individuals are spaced evenly from one another.



Clumped

In a clumped population, such as these striped catfish, several individuals are packed closely together.

Figure 5-2

Patterns of Distribution

The dots in the inset illustrations represent individual members of a population. **Compare** How do the three types of distribution differ from one another?

INTERACTIVITY

Learn about the ways populations may be described.

Density and Distribution

The number of individuals that can be found per unit area is called an area's **population density**. Different species can have very different densities, even in the same environment. A population of ducks in a pond may have a very low density, while algae that cover the pond surface have a high density. Why does population density matter? A few, widely spaced lionfish entering a new environment might not disturb existing communities very much. But these invaders can reach densities of over 200 adults per acre. And at that density, they can eat more than 460,000 other fish each year! In some places, lionfish have already devoured as much as 90 percent of the local species they eat!

Population distribution describes the way individuals are spaced out across their range. **Figure 5-2** shows three main distribution patterns: random, uniform, and clumped. Some patterns serve a purpose. Clumping, for example, can help animals avoid predators. Uniform distribution can result when individuals compete with one another for space or other resources. A random distribution occurs when the location of an individual in a population is independent of other individuals.

Age Structure

To fully understand a plant or an animal population, researchers need to know more than just the number of individuals it contains. They also need to know the ages of those individuals, and how many of them are male, and how many are female. Those data describe the **age structure** of the population. Why is that information important? Because most plants and animals cannot reproduce until they reach a certain age. Also, among animals, only females can produce offspring.

READING CHECK **Summarize** What is the difference between population density and population distribution?

Population Growth

What determines whether a population increases, decreases, or stays the same size? A population will increase or decrease in size depending on how many individuals are added to it or removed from it, as shown in **Figure 5-3**. ***Birthrate, death rate, and the rate at which individuals enter or leave a population all affect population growth.***

VIDEO

Explore the effect of birth rate versus death rate as it applies to population growth in this interactive video.

Birthrate and Death Rate

Populations can increase if more individuals are born in any period of time than die during that same period. In other words, a population can increase when its birthrate is higher than its death rate. Note that *birth* means different things in different species, and that species vary wildly in the amount of young they produce. Sea otters are born much like humans are born, usually one at a time. Lionfish, on the other hand, release as many as 15,000 eggs at once!

If the birthrate equals the death rate, the population may stay the same size. But if the death rate is greater than the birthrate, the population will decrease. That's what happened to sea otters. Otters breed once every year or two, and usually give birth to only one pup each time. Intensive hunting during the eighteenth century raised the otter death rate so high that births couldn't keep up.

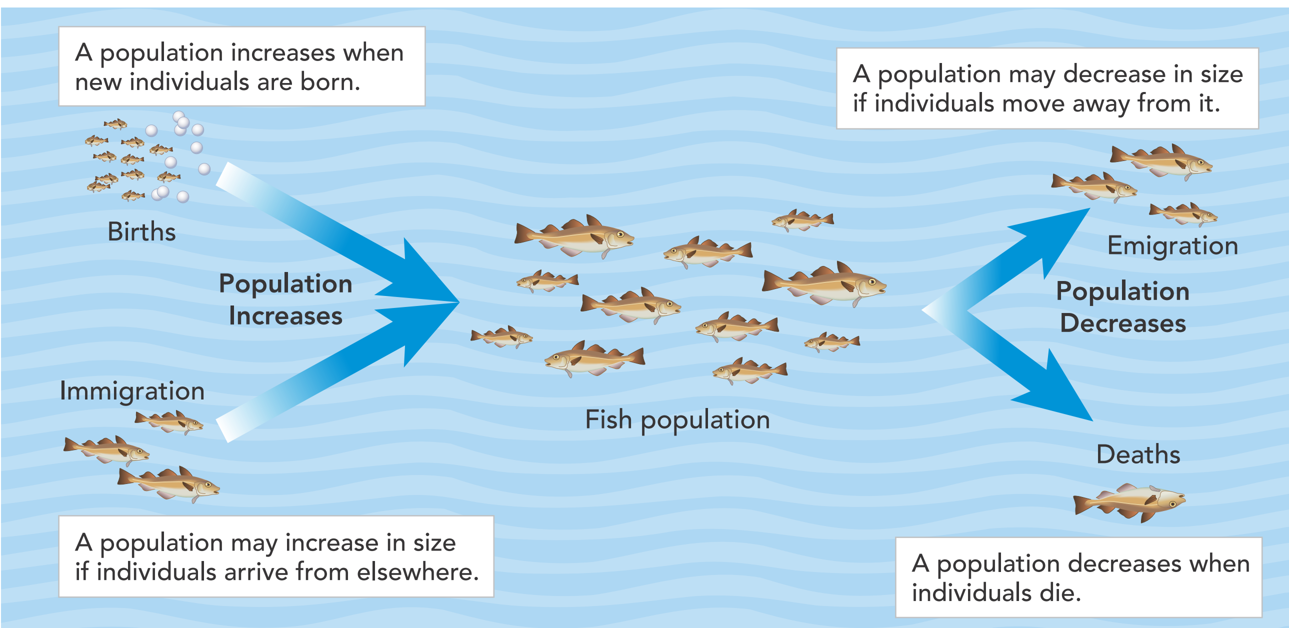
Lionfish, by contrast, appear to have no predators or other natural enemies in the Atlantic. In the Atlantic, the lionfish death rate is lower than in their native range, and their "birth" rate is very high. Many dive groups have launched campaigns to hunt the invading fish, trying to increase their death rate and cause the population to decrease. Lionfish, it so happens, are quite tasty, and several chefs have produced a "Lionfish Cookbook" in an effort to encourage divers to hunt these invasive animals. But with a birthrate as high as lionfish have, human hunting can barely put a dent in their population.

CASE STUDY

Figure 5-3

Factors That Affect Population Growth

The numbers of individuals that are born, that die, or that enter or leave a population affect the growth of a population. **Use Models** How would you expand this model to include the effects of fishing on this population?



Immigration and Emigration A population may increase if individuals move into its range from elsewhere, a process called **immigration**. Suppose, for example, that an oak grove in a forest produces a bumper crop of acorns one year. The squirrel population in that grove may increase as squirrels from nearby areas immigrate in search of food. On the other hand, a population may decrease in size if individuals move out of the population's range, a process called **emigration**. A local food shortage or a lack of another limiting resource can cause emigration. Young animals may emigrate from the area where they were born to find mates or establish new territories.

How quickly organisms immigrate and emigrate depends, in part, on how far they travel, how quickly they move, and whether or not human activity moves them around. Sea otters, for example, don't migrate or travel very far from their home turf. Lionfish, on the other hand, live for several weeks as larvae that float wherever currents take them. That's one reason lionfish are showing up as far north as Boston, because their larvae are carried north from Florida by the Gulf Stream. Lionfish didn't immigrate into the Atlantic on their own, but were released into the wild by home aquarium keepers who had bought them as pets.

Exponential Growth

If you provide a population with all the food and space it needs, protect it from predators and disease, and remove its waste products, the population will increase. Why? Because members of the population will survive and produce offspring. Later, those offspring will produce their own offspring. Then, the offspring of *those* offspring will reproduce.

Although the birthrate may be more or less constant, the rate of population growth changes. Why? Because each generation contains more individuals than the generation before it! The population increases rapidly as more and more offspring are produced in a situation called **exponential growth**. ***Under ideal conditions with unlimited resources, a population will increase exponentially. This means that the larger the population gets, the faster it grows.***

BUILD VOCABULARY

Related Words An *exponent* indicates the number of times a number is multiplied by itself. The adjective **exponential** describes something that is expressed using exponents—such as the rate of growth.

HS-LS2-1

Argument-Based Inquiry **Guided Inquiry**

Estimating Population Size

Problem How can you estimate the size of a large population of plants, animals, or other living things?

In this lab, you will estimate the size of various populations in a model ecosystem. Then you will use mathematical representations to explain the factors that affect the carrying capacity of the model ecosystem for the species.

Find this lab online in your digital course.

Organisms That Reproduce Rapidly

Let's say that we begin a hypothetical experiment with a single bacterium that divides to produce two cells every 20 minutes. We supply it with ideal conditions—and watch. After 20 minutes, the bacterium divides to produce two bacteria. After another 20 minutes, those two bacteria divide to produce four cells. At the end of the first hour, those four bacteria divide to produce eight cells.

Do you see what is happening? After three 20-minute periods, we have 2 × 2 × 2, or 8, cells. Another way to say this is to use an exponent: 2^3 cells. In another hour (six 20-minute periods), there will be 2^6, or 64, bacteria. In just one more hour, there will be 2^9, or 512. In one day, this bacterial population will grow to an astounding 4720 quintillion individuals (A quintillion is written as the digit "1" followed by 18 zeroes!) What would happen if this growth continued without slowing down? In a few days, this bacterial population would cover the planet!

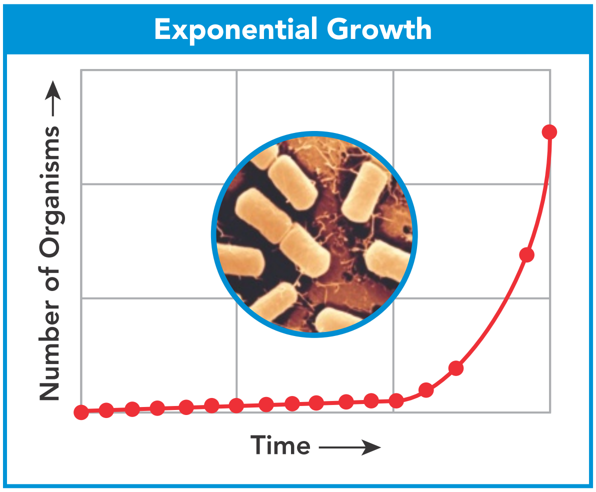


Figure 5-4

Exponential Growth

In the presence of unlimited resources and in the absence of predation and disease, populations will increase exponentially. The characteristic J-shape of the graph shows exponential growth.

If you plot the size of this population on a graph over time, you get a curve shaped like the letter "J." This J-shaped curve rises slowly at first, and then rises faster and faster, as shown in **Figure 5-4**. If nothing interferes with this exponential growth, the population will become larger and larger, faster and faster.

Organisms That Reproduce Slowly Of course, many organisms grow and reproduce much more slowly than bacteria. For example, a female elephant can produce a single offspring only every two to four years. Newborn elephants take about ten years to mature. But, if exponential growth continued indefinitely, the result would still be impossible. In the unlikely event that all descendants of a single elephant pair survived and reproduced, after 750 years there would be nearly 20 million elephants!

Organisms in New Environments Sometimes, when an organism migrates or is moved to a new environment, its population grows exponentially for a time. That's happening with lionfish in the Atlantic. It also happened when a few European gypsy moths were accidentally released from a laboratory near Boston. Within a few years, these plant-eating pests had spread across the northeastern United States. In peak years, gypsy moth caterpillars devour the leaves of thousands of acres of forest. In some places, they form a living blanket that covers the ground, sidewalks, and cars!

READING CHECK Calculate How many bacteria will there be after four hours from a single bacterium that divides to produce two cells every 15 minutes?

READING TOOL

As you read about the growth of populations in nature, list the phases of growth in the order in which they occur. Describe each phase in your own words.

Logistic Growth

If you think about it, the ability of populations to grow exponentially presents a pretty clear puzzle. Obviously, bacteria, lionfish, and gypsy moths don't cover Earth or fill the oceans! This means that natural populations don't grow exponentially for long. Sooner or later, something—or several "somethings"—stop exponential growth. What happens?

Phases of Growth One way to begin answering this question is to watch how populations behave in nature. **Figure 5-5** traces the phases of growth that a population goes through after a few individuals are introduced into a real-world environment.

Phase 1: Population Grows Rapidly After a short time, the population begins to grow exponentially. During this phase, resources are unlimited, so individuals grow and reproduce rapidly. Few individuals die, and many offspring are produced, so both the population size and the rate of growth increase more and more rapidly.

Phase 2: Growth Slows Down In real-world populations, exponential growth does not continue for long. At some point, the rate of population growth begins to slow down. This growth slow down is due to a variety of limiting factors such as competition for resources. This does not mean that the population size decreases. The population still increases, but the rate of growth slows down, so the population size increases more slowly.

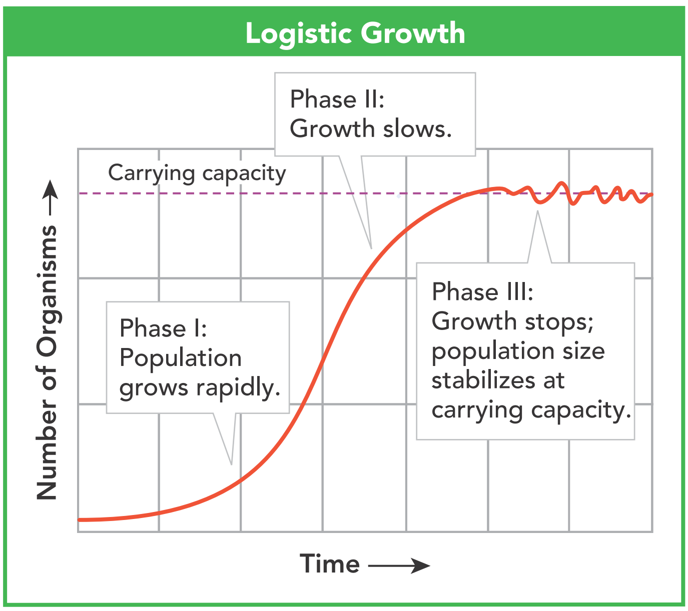
Phase 3: Growth Stops At some point, the rate of population growth drops to zero. This means that the size of the population levels off. Under some conditions, the population will remain at or near this size indefinitely.

INTERACTIVITY

Figure 5-5

Logistic Growth

Real-world populations show the characteristic S-shaped curve of logistic growth. As resources become limited, population growth slows or stops, leveling off at the carrying capacity.



The Logistic Growth Curve The curve in **Figure 5-5** has a shape like the letter "S." This S-shaped curve represents what is called **logistic growth**. ***Logistic growth occurs when a population's growth slows and then stops, following a period of exponential growth.*** Many familiar plant and animal populations follow a logistic growth curve.

What changes in a population's growth rate produce a logistic curve? Remember that a population increases when more organisms are added to it, such as by birth, than leave the population, such as by dying. Thus, population growth may slow for several reasons. Growth may slow if the birthrate decreases.

Growth may also slow if the death rate increases—as it did for otters when they were hunted. Rates of immigration and emigration also affect population growth.

Carrying Capacity A population will stop growing when a population's birthrate and death rate are the same, and when immigration equals emigration. The population size may still rise and fall somewhat, but the ups and downs average out around a certain population size.

Look again at **Figure 5-5**. You will see a jagged, horizontal line through the region of the graph where population growth levels off. The point at which that line intersects the *y*-axis represents what ecologists call the carrying capacity. **Carrying capacity** is the maximum number of individuals of a particular species that a particular environment can support. Once a population reaches the carrying capacity of its environment, a variety of biotic and abiotic external factors affect the population in ways that stabilize it at that size. In **Figure 5-6**, you can see the effect of seasonal changes on migration patterns of wildebeests.

Figure 5-6

Carrying Capacity and Seasonal Changes

Seasonal changes in food availability in different parts of the species range cause seasonal changes in the carrying capacity of certain environments for wildebeests and other African ungulates. These seasonal changes in carrying capacity drive Africa's extraordinary migrations.

HS-LS2-1, HS-LS2-2

LESSON 5.1 Review

KEY QUESTIONS

1. What characteristics do ecologists study to learn about populations?
2. What factors determine the rate at which a population is increasing or decreasing?
3. What happens to the growth of a population when resources are unlimited?
4. How does logistic growth occur?

CRITICAL THINKING

5. **Develop Models** A scientist is using a computer model to predict changes to a population of rabbits in a meadow. Identify the information about the rabbit population that should be included in the computer model.
6. **Identify Variables** A population of 5000 longhorn beetles lives in a tract of forest. What variables would affect the rate at which the population increases or decreases?

LESSON 5.2

Limits to Growth

KEY QUESTIONS

- *What factors determine carrying capacity?*
- *What limiting factors depend on population density?*
- *What limiting factors do not typically depend on population density?*
- *What is the relationship between limiting factors and extinction?*

HS-LS2-1: Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
HS-LS2-2: Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
HS-LS2-6: Evaluate the claims, evidence, and reasoning that the complex interactions in ecosystems maintain relatively consistent numbers and types of organisms in stable conditions, but changing conditions may result in a new ecosystem.
HS-LS4-5: Evaluate the evidence supporting claims that changes in environmental conditions may result in: (1) increases in the number of individuals of some species, (2) the emergence of new species over time, and (3) the extinction of other species.

VOCABULARY

limiting factor
density-dependent limiting factor
density-independent limiting factor

READING TOOL

As you read, compare and contrast density-dependent limiting factors and density-independent limiting factors. Complete the Venn diagram in your **Biology Foundations Workbook.**

If populations are theoretically able to grow exponentially, why do they often show logistic growth in the real world? One reason is predation. One factor that limits warthog populations in part of Africa is predation by lions. Now, think about lionfish. In their native Pacific habitats, lionfish populations increase in size until they reach carrying capacity. Then population growth stops because some combination of factors limits their population size. In the Atlantic and Caribbean, however, lionfish populations are growing out of control. Why does a species that is "well-behaved" in one environment become a pest in another?

Limiting Factors

Recall that growth of primary producers can be controlled by a limiting nutrient. A limiting nutrient is a specific example of a more general ecological concept called a limiting factor. A **limiting factor** is any factor that controls the growth of a population. Limiting factors are either biotic or abiotic environmental factors that affect members of the population. The strength of some interactions depends on the density of the population. Other interactions act in more or less the same way regardless of population density. ***Acting separately or together, limiting factors determine the carrying capacity of an environment for a species.*** Often, although not always, limiting factors keep most populations in their natural habitat at a population size somewhere between extinction and overrunning the ecosystem.

Charles Darwin recognized that long-term population growth and species survival are often dependent on limiting factors. Ecological limiting factors produce the pressures of natural selection that stand at the heart of Darwin's evolutionary theory.

READING CHECK **Stability and Change** How do limiting factors affect the population of a species?

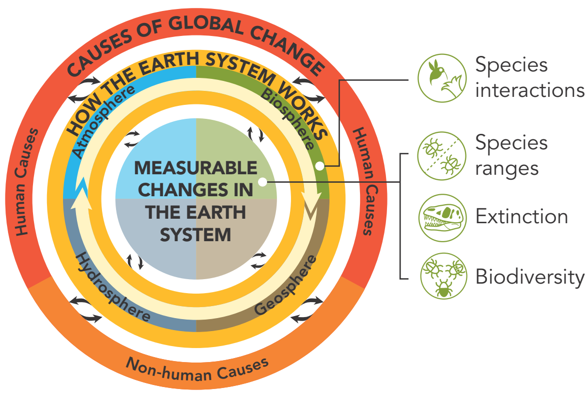
Density-Dependent Limiting Factors

Limiting factors that operate strongly when the number of organisms per unit area, or population density, reaches a certain level are called **density-dependent limiting factors**. These factors do not strongly affect small, scattered populations. ***Density-dependent limiting factors include competition, stress from overcrowding, parasitism, disease, predation, and herbivory.*** Note that some of these involve abiotic factors, and others involve biotic factors.

Figure 5-7

Competition

Species interactions, such as competition, parasitism, disease, stress from overcrowding, predation, and herbivory, can result in changes in species populations, leading to changes in species ranges or biodiversity.



Competition

When populations become crowded, individuals compete for food, water, space, sunlight, and other potentially limiting resources. Some individuals obtain enough resources to survive and reproduce. Others may obtain enough to survive but not enough to raise offspring. Still others may starve or die from lack of shelter. Thus, competition for limiting resources can decrease birthrates, increase death rates, or both.

Competition is a density-dependent limiting factor, because the more individuals that are present in an area, the sooner they use up the available resources. Many animals compete for the territory they use to find food, to make a home, and to breed. Small animals might compete for a very specific territory. Individuals that can't establish and defend a territory cannot breed.

Competition can also occur among members of different species. In many cases, members of different species attempt to use similar or overlapping resources that are limited. This type of competition is a major force behind evolutionary change.

Parasitism and Disease

When parasites and disease-causing organisms feed, they weaken their hosts and cause stress or even death. Parasitism and disease are density-dependent effects because the denser the host population, the more easily parasites can spread from one host to another.

Stress From Overcrowding

Some species fight amongst themselves if overcrowded. In some species, such as chimpanzees, the winner in a fight may kill his opponent. In other cases, constant fighting can cause stress, which weakens the body's ability to resist disease. Overcrowding can have other effects, too. In some species, overcrowding stress can cause females to neglect, kill, or even eat their own offspring. Thus, overcrowding can lower birthrates, raise death rates, or both. Stress can also increase rates of emigration.

Figure 5-8

Parasitism

The ticks in this dog's ear are parasites but also often carry disease-causing organisms.

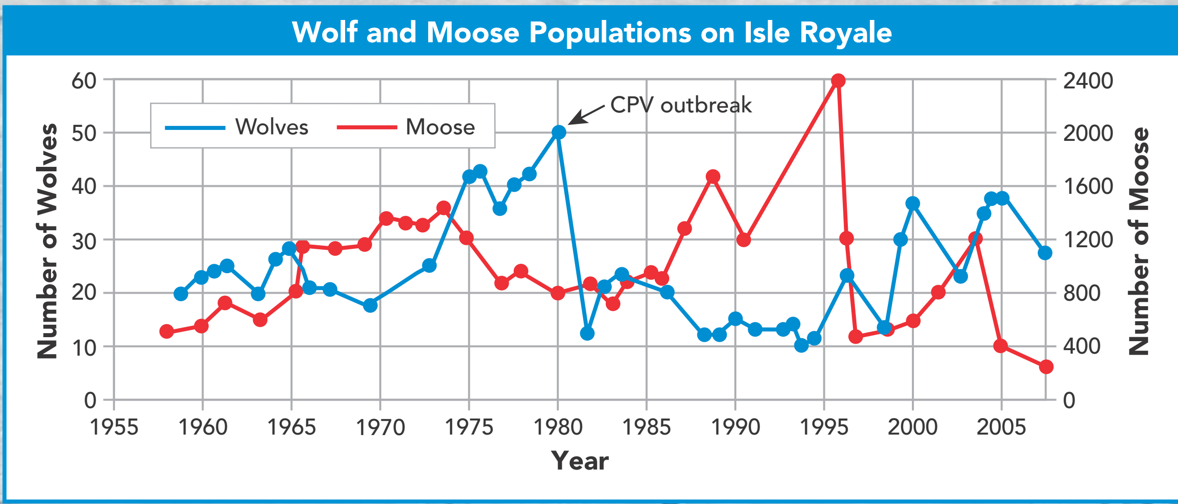


Figure 5-9

Moose-Wolf Populations on Isle Royale

These data showing changes in moose and wolf populations on Isle Royale illustrate how predators (wolves) affect prey populations (moose), and how availability of prey affects predator populations. The moose population was also affected by a change in their food supply (plants). At one point, the wolf population decreased due to a canine parvovirus (CPV). ✓ **Interpret Graphs** How do differences between the peaks and valleys of the two graphs demonstrate interactions between these populations?

BUILD VOCABULARY

Academic Words The verb fluctuate means "to rise and fall as if in waves." A population that fluctuates is unstable. Its numbers go up and down rapidly.

INTERACTIVITY

Learn about the effects of limiting factors on a population.

Predation and Herbivory

The effects of predators on prey and the effects of herbivores on plants are important density-dependent population controls. One classic study focuses on the relationship between wolves, moose, and plants on Isle Royale, an island in Lake Superior. The graph in **Figure 5-9** shows how populations of wolves and moose fluctuated over the time the study was done. What drives these changes in population size?

Predator-Prey Relationships Populations of predators and prey may rise and fall over time. Sometimes, the moose population on Isle Royale increases enough that moose become easy prey for wolves. When wolves have plenty to eat, their population increases. As the wolf population increases, wolves begin to kill more moose than are born. This causes the moose death rate to rise higher than the birthrate, so the moose population decreases. As the moose population decreases, wolves begin to starve. Starvation raises the wolves' death rate and lowers their birthrate, so the wolf population also decreases. When only a few predators are left, the moose death rate drops, and the cycle may repeat.

Notice that the graph in **Figure 5-9** shows a dramatic drop in the wolf population after 1980. At that time, a virus accidentally introduced to the island killed all but 14 wolves—and all but three females. This drop in the wolf population enabled moose populations to skyrocket to 2400. Those densely packed moose then became infested with winter ticks that caused hair loss and weakness.

Herbivore Effects Herbivory can also contribute to changes in population size. From a plant's perspective, herbivores are predators. So it isn't surprising that populations of herbivores and plants cycle up and down, just like populations of predators and prey. On parts of Isle Royale, large, dense moose populations can eat so much balsam fir that the population of these favorite food plants drops. When this happens, moose may suffer from lack of food.

Humans as Predators In some situations, human activity limits populations. For example, eighteenth-century hunters killed many otters, greatly increasing the population death rate. Otters' birthrate of just one or two pups every year or two just couldn't keep up. As a result, the otter populations decreased. Since the beginning of the twentieth century, otter populations have been recovering, because hunting stopped. If hunting otters significantly decreased their population size, could hunting lionfish do the same? That's theoretically possible, but lionfish are hard to catch using hook and line or big nets. And it is unlikely that hunting them one at a time with hand nets could make any difference, given that females can produce thousands of eggs at a time!

READING CHECK **Describe** How does competition affect a population?

READING TOOL

Make a two-column chart. List examples of density-dependent limiting factors you have read about in this text and note their effects on populations.

Figure 5-10

Plant-Herbivore Interactions

Plants are the "prey" of herbivores. Interactions between herbivore populations and plant populations can experience the same kinds of fluctuations that occur between predators and prey.

HS-LS2-2

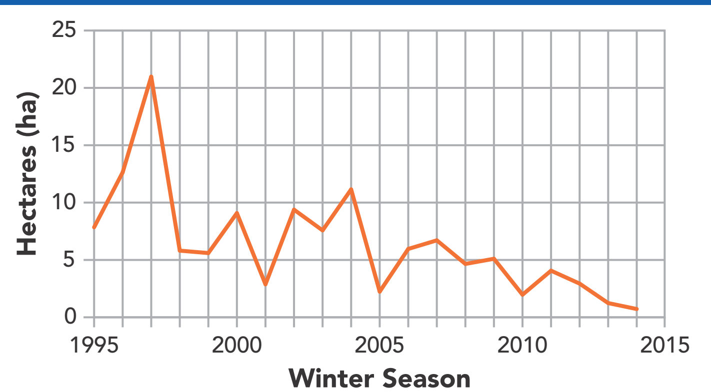
Analyzing Data

Monarchs in Decline

Every year, monarch butterflies migrate between their summer homes in the north and their winter homes in tropical regions, such as Mexico. The line graph shows the changing winter population of monarchs in Mexico. Data from other monarch homes confirm a similar trend.

1. **Analyze Graphs** What trend in the monarch population does the graph show?
2. **Evaluate Claims** A student claims that the monarch population increases and decreases in a cycle, similar to the pattern of predator-prey populations like wolves and moose. Use the data to evaluate this claim.
3. **Ask Questions** What questions would you ask to identify the limiting factors that are affecting the monarch population?

Total Area Occupied by Overwintering Monarchs



Source: Monarchwatch.org

Density-Independent Limiting Factors

Density-independent limiting factors affect all populations regardless of population size and density. ***Environmental extremes—including weather extremes such as hurricanes, droughts, or floods, and natural disasters such as wildfires—can act as density-independent limiting factors.*** In response to such factors, a population may "crash." After the crash, the population may build up again quickly, or it may stay low for some time.

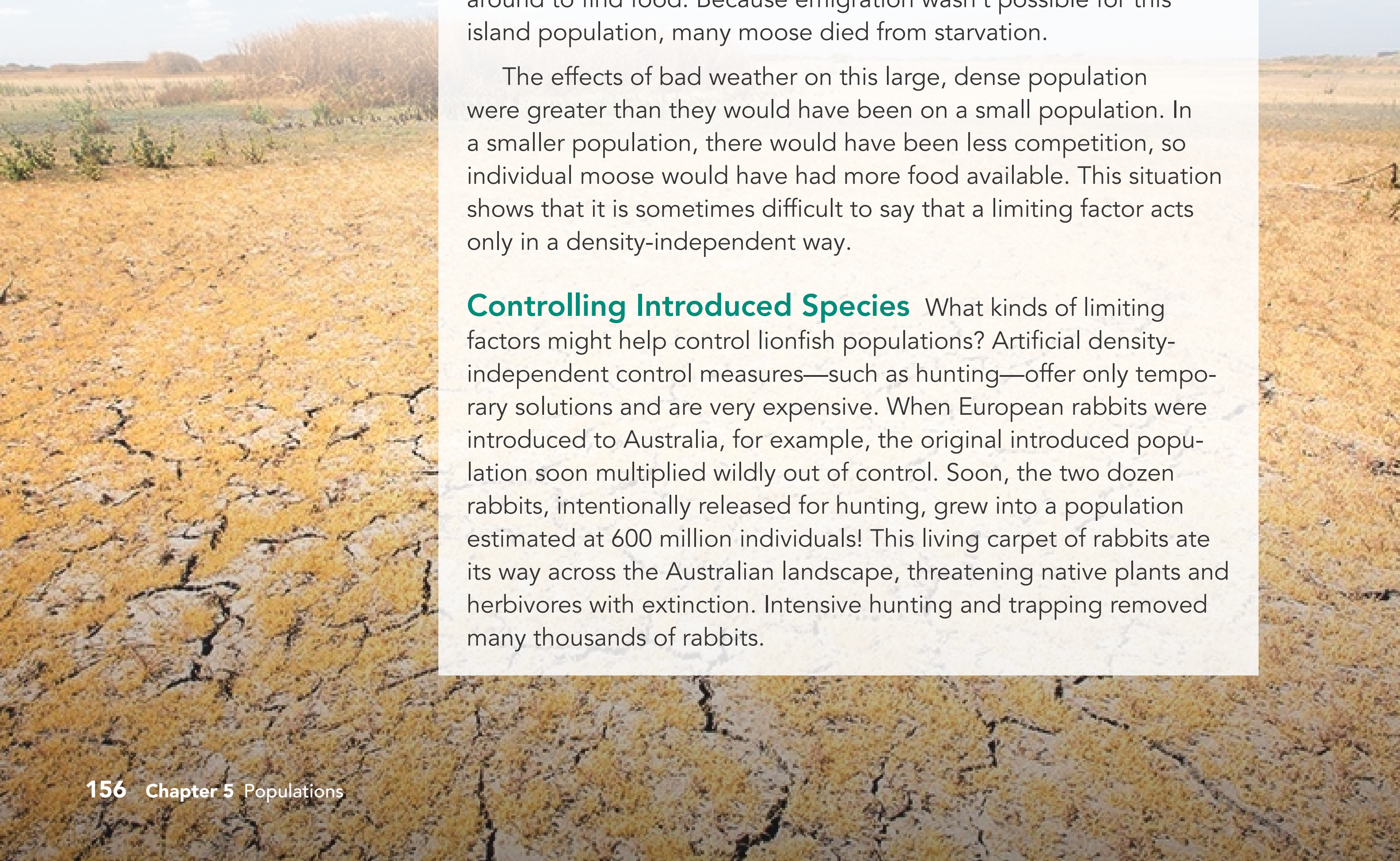
Storms can nearly extinguish local populations of some species. For example, aphids, and other leaf-eating insects can be washed out by a heavy rainstorm. Waves whipped up by hurricanes can devastate coral reefs. Extremes of cold or hot weather can also take their toll, no matter how sparse or dense a population is. More prolonged environmental changes include severe drought, shown in **Figure 5-11**. These changes can cause severe declines in population sizes. If affected populations do not recover, these kinds of environmental changes can affect ecosystem stability. California's long-term drought, along with human-caused environmental change, is affecting populations of plants, insects, and birds.

INTERACTIVITY

Figure 5-11

Density-Independent Limiting Factors

Kern Valley Wildlife Refuge in California is an important nesting ground for migrating birds and waterfowl. As a result of four years of drought, the lake bed dried up and the migrating birds have nowhere to go.



True Density Independence?

Sometimes, effects of so-called density-independent factors actually vary with population density. On Isle Royale, for example, the moose population grew exponentially for a time after the wolf population crashed. Then, a bitterly cold winter with very heavy snowfall covered the plants that moose feed on, making it difficult for all those moose to move around to find food. Because emigration wasn't possible for this island population, many moose died from starvation.

The effects of bad weather on this large, dense population were greater than they would have been on a small population. In a smaller population, there would have been less competition, so individual moose would have had more food available. This situation shows that it is sometimes difficult to say that a limiting factor acts only in a density-independent way.

Controlling Introduced Species

What kinds of limiting factors might help control lionfish populations? Artificial density-independent control measures—such as hunting—offer only temporary solutions and are very expensive. When European rabbits were introduced to Australia, for example, the original introduced population soon multiplied wildly out of control. Soon, the two dozen rabbits, intentionally released for hunting, grew into a population estimated at 600 million individuals! This living carpet of rabbits ate its way across the Australian landscape, threatening native plants and herbivores with extinction. Intensive hunting and trapping removed many thousands of rabbits.

Figure 5-12

Overrun by Rabbits

Rabbits breed very quickly. Overly large populations of rabbits have had devastating effects on island ecosystems—including islands the size of Australia. Even extensive hunting could not control the rabbits in Australia.

But these density-independent efforts at population control couldn't stop the invasion, as shown in **Figure 5-12**. Finally, in 1950, after careful experimentation, a lethal virus that causes a rabbit disease called myxomatosis was introduced into the rabbit population. That density-dependent control effort was originally very successful. But over time, rabbits evolved resistance to the disease, and less deadly viral strains also evolved. Not surprisingly, efforts to control lionfish populations in the Caribbean have had very limited success. Ecologists are trying to identify density-dependent limiting factors that control lionfish in their natural habitats. So far … no luck.

INTERACTIVITY

Conduct an experiment to see how the introduction of a non-native species affects a native population.

Limiting Factors and Extinction

Limiting factors do not always stay the same over time. Temperature and rainfall, for example, are limiting factors for some organisms in certain environments. Both temperature extremes and rainfall patterns can change if climate changes. Available space for feeding and other activities can also be a limiting factor for many animals. So when human activities divide natural environments into small pieces, the carrying capacity of those pieces of habitat for those species can be much smaller. ***If carrying capacity falls low enough, populations can be wiped out, leading to species extinction.***

HS-LS2-1, HS-LS2-2, HS-LS2-6, HS-LS4-5

LESSON 5.2 Review

KEY QUESTIONS

1. What is a limiting factor?
2. Why are competition, predation, herbivory, parasitism, disease, and stress from overcrowding density-dependent limiting factors?
3. What happens to a population in response to a density-independent limiting factor?
4. What may cause a species to become extinct?

CRITICAL THINKING

5. **Apply Scientific Reasoning** How could a change to an ecosystem increase the carrying capacity for one species and decrease it for another? Include an example in your answer.
6. **Synthesize Information** In a dense forest, trees compete with one another for space to grow and for sunlight. Although all trees need water, why is water not generally a limiting factor in the forest?

LESSON 5.3 Human Population Growth

KEY QUESTIONS

- *How has human population size changed over time?*
- *Why do population growth rates differ among countries?*

HS-LS2-1: Use mathematical and/or computational representations to support explanations of factors that affect carrying capacity of ecosystems at different scales.
HS-LS2-2: Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.
HS-ESS3-1: Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

VOCABULARY

demography
demographic transition

READING TOOL

As you read, explain the three stages of The Demographic Transition. Complete the graphic organizer in your **Biology Foundations Workbook.**

Human populations—locally and globally—increase, remain the same, or decrease because of the same factors that affect the population growth of other species. How quickly is global human population growing today? In the United States and other developed countries, population growth has slowed. But in some developing countries, the population is still growing rapidly. Worldwide, four humans are born every second. With this birthrate, the human population is on its way to reaching 9 billion during your lifetime. What do the present and future of human population growth mean for our species and its interactions with the rest of the biosphere?

Historical Overview

Human populations, like other populations, tend to increase, and the rate of those increases has changed over time. For most of human existence, our population grew slowly. Food was hard to find. Predators and diseases were common and life-threatening. These limiting factors caused high death rates. Until a few decades ago, only half the children in the world survived to adulthood. With death rates so high, families had many children, just to make sure that some would survive.

Exponential Human Population Growth As countries became more developed, food supplies became more reliable, and the global human population began to grow more rapidly. That trend continued through the Industrial Revolution in the 1800s. In addition to improved nutrition, improvements in sanitation, medicine, and public health dramatically reduced death rates. Yet, birthrates in much of the world remained high. The combination of lower death rates and high birthrates led to exponential growth. It took 123 years for the human population to double from 1 billion in 1804 to 2 billion in 1927. Then it took just 33 years for it to grow by another billion.

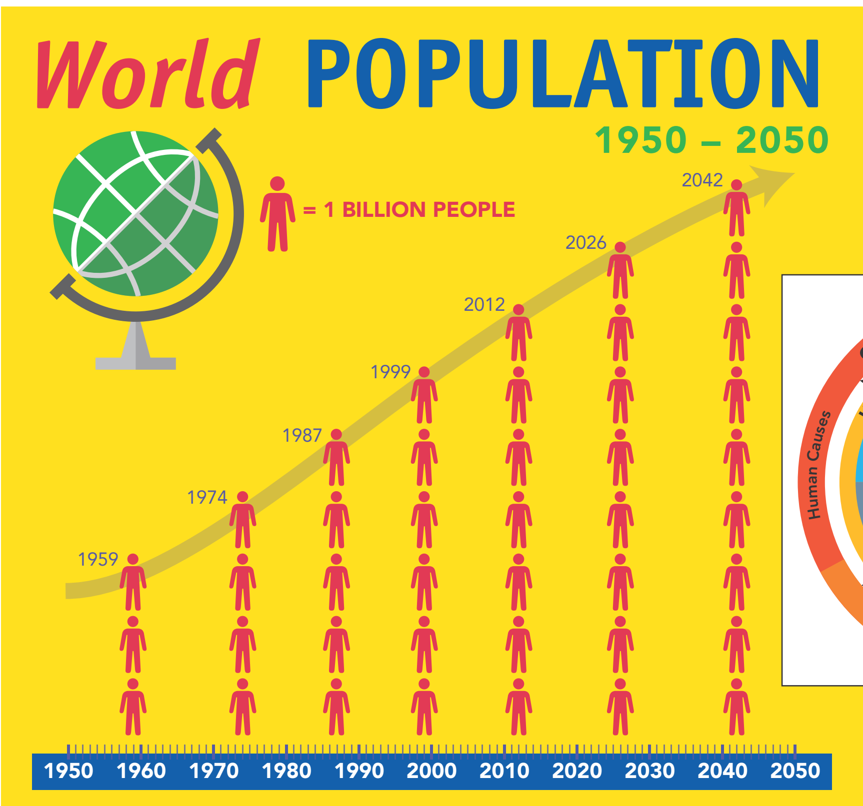
The time it took for the population to increase each additional billion continued to fall until 1999, when it began, very slowly, to rise.

The Predictions of Malthus As you've learned, exponential growth cannot continue forever. Two centuries ago, this problem troubled English economist Thomas Malthus, who argued that survival of human populations is dependent on limited resources. Malthus suggested that only war, famine, and disease could limit human population growth. Can you see what Malthus was suggesting in biological terms? He thought that human populations would be regulated by competition (war), limited resources (famine), parasitism (disease), and other density-dependent factors. This aspect of Malthus's work was vitally important in shaping Charles Darwin's thinking about natural selection.

World Population Growth Slows Exponential growth of the global human population continued until the second half of the twentieth century. The global human population growth rate reached a peak around 1959. That growth rate then decreased sharply for a couple of years before rising again. Since the mid 1960s the growth rate of our global population has been slowly decreasing. Note that we are talking about increases and decreases in the rate of growth, not of the total population. Global human population has continued to increase over this entire period, as shown in **Figure 5-13**. The decrease in growth rate just means that our population is growing more slowly now than it did during most of the twentieth century.

INTERACTIVITY

Explore human population growth and compare population growth with population growth rate.



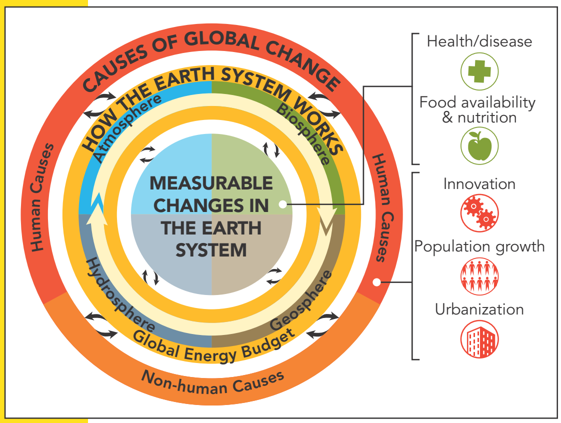
Source: U.S. Census Bureau, International Data Base, August 2016 Update.

CASE STUDY

Figure 5-13

World Population Growth

The world's human population has increased because of improved nutrition and innovations such as sanitation and medicine, reducing death rates while birthrates remained high. However, the rate of growth has been decreasing. The future will likely bring moderate growth or a steady population size.



CASE STUDY Quick Lab Open-Ended Inquiry

Modeling Population Changes

1. Use counters to model a population. Prepare a data table to record the changes to population size.
2. Choose a birthrate and death rate to model. Then, add and remove counters to represent the rates for one year. Record the new population size. Repeat to model the changing population over several years.
3. Repeat the procedure to model other combinations of birthrates and death rates.

ANALYZE AND CONCLUDE

1. **Use Models** When did the model show the greatest population increase? When did it show the greatest population decrease?
2. **Revise Models** How could you revise the model to show age structure?

Patterns of Human Population Growth

The scientific study of human populations is called **demography**. Demography examines characteristics of human populations and attempts to explain how those populations will change over time. Scientists have identified several social and economic factors that affect human population growth. ***Birthrates, death rates, and the age structure of a population help predict why some countries have high growth rates while other countries' populations increase more slowly.***

BUILD VOCABULARY

Prefixes The prefix *demo-* means "people" or "population." A **demographic transition** is a change in a population.

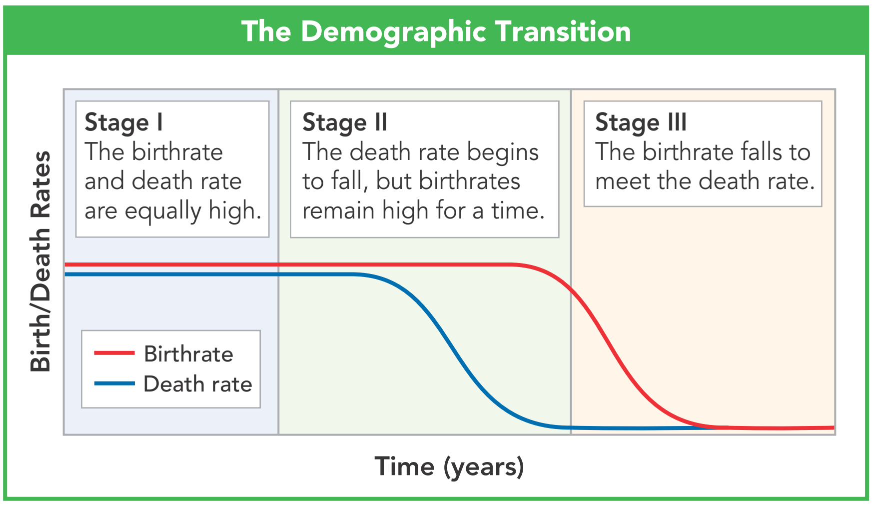
The Demographic Transition Human societies had equally high birthrates and death rates during most of history. But during the past century, population growth in the United States, Japan, and much of Europe slowed dramatically. Demographers developed a hypothesis to explain this shift. According to this hypothesis, these countries have completed the **demographic transition**, a dramatic change from high birthrates and death rates to low birthrates and death rates.

The demographic transition is divided into three stages, as shown in **Figure 5-14**. The United States, for example, passed through Stage 2 between 1790 and 1910. Parts of South America, Africa, and Asia are passing through Stage 2 now.

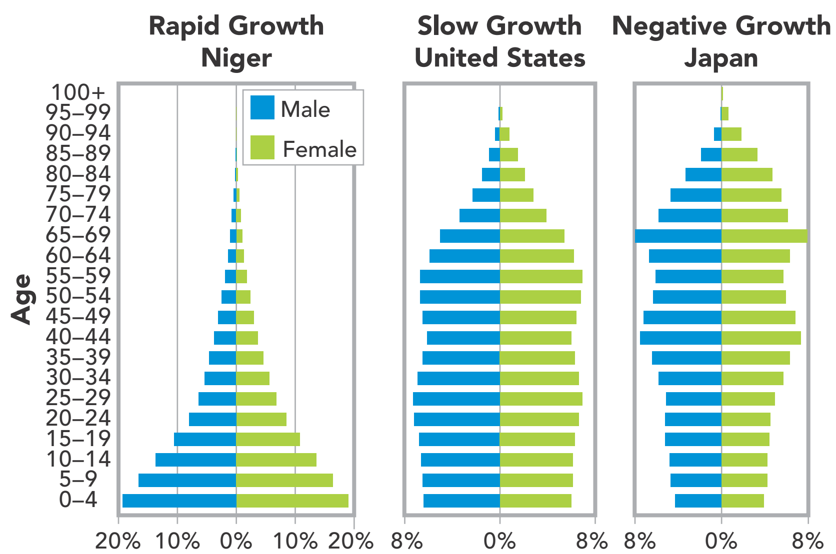
Figure 5-14

Demographic Transition

Human birthrates and death rates were high for most of history (Stage 1). Advances in nutrition, sanitation, and medicine led to lower death rates. Birthrates remained high for a time, so births greatly exceeded deaths (Stage 2), and the population increased exponentially. As levels of education and living standards rose, families had fewer children, and the birthrate fell (Stage 3), and population growth slowed. The demographic transition is complete when the birthrate meets the death rate, and population growth stops.



Three Patterns of Population Change



Source: United Nations, World Population Prospects

INTERACTIVITY

Figure 5-15

Population Age Structure

The age structure of a population reveals how fast a population is growing. **Interpret Graphs** How can you tell that Japan has a negative growth rate?

A large part of ongoing human population growth is happening in only ten countries, with India, China, and sub-Saharan Africa in the lead. Our J-shaped exponential growth curve may be changing into a logistic growth curve, but in the meantime, global human population is still growing.

Age Structure and Population Growth Age structure diagrams, such as those in **Figure 5-15**, compare the number of people in different age categories. The age structure of a population reveals how fast a population is growing—a greater percentage of young people indicate a growing population, and a greater percentage of older people indicate a shrinking population. In the United States, there are nearly equal numbers of people in each age group, indicating that our population is growing slowly. The population of Niger is increasing, while the population of Japan is decreasing slightly.

Demographers consider many factors to predict human population growth. The factors include the age structure, the effects of deadly diseases such as AIDS, malnutrition, and death rates. Current projections suggest that by 2050 the world population will reach 9 billion people.

INTERACTIVITY

Investigate four different countries and the factors that determine their population growth.

HS-LS2-1, HS-LS2-2

LESSON 5.3 Review

KEY QUESTIONS

1. How has the human population size changed throughout history?
2. What factors help explain the differences in human population growth in different countries?

CRITICAL THINKING

3. **Ask Questions** What questions should you ask to determine whether a population has passed through a demographic transition?
4. **Analyze Graphs** Review the age structure graphs shown in **Figure 5-15**. How do patterns in the graphs indicate the rate at which a population is increasing or decreasing?

CASE STUDY WRAP-UP

What can we learn from China?

China is home to about 1.4 billion people, making it the most populous country in the world. Efforts of the Chinese government to control population growth are worth studying.

HS-LS2-2, HS-LS2-7, HS-ETS1-1

Make Your Case

For almost 40 years, the Chinese government used a one-child policy to curb a large and rapidly growing population. Many Chinese families complied with the policy, but others resisted. Violators often were punished, sometimes cruelly. Data suggest that the policy helped keep the population in check. Are there lessons here for the rest of the world?

Develop a Solution

1. **Define the Problem** Do you think issues resulting from the world's growing human population could affect global society? Conduct research to define issues and challenges, and evaluate their severity.
2. **Evaluate a Solution** Do you think China's one-child policy was justified? What alternatives, if any, do you think would have been preferable? Did the policy reduce the impacts of human activity on the environment, and if so, how? Could a similar policy be implemented elsewhere? Research China's policy and its long-term effects. Cite data, evidence, and other information you learn to support your evaluation.

Society on the Case

A Deadly Lesson

For much of history, people wandered in groups or lived in small communities. Then agriculture and other technologies fueled the growth of cities. Cities were vital in the development of great civilizations. But their high population densities meant that city dwellers were more vulnerable to density-dependent population limiting factors, including disease.

Some diseases were chronic problems. One of the worst was a deadly intestinal disease called cholera, which first appeared in India centuries ago. During the Industrial Revolution, cholera spread around the world, appearing in England in 1831. Over the next 20 years, cholera epidemics claimed thousands of lives worldwide. Physicians could do nothing to stop it. There was no cure, and no one understood how it spread. (The discovery that microscopic organisms could cause disease hadn't happened yet.)

Finally, in 1854, English physician John Snow hypothesized that cholera was somehow spread through contaminated water. By carefully examining public records and data from hospitals, Snow identified a single water pump as the source of the outbreak. As it turned out, sewage had mixed into the water drawn from that pump. Years later, scientists identified the bacteria that causes cholera, which is spread by sewage.

Snow is often called the father of epidemiology, the study of public health. His work showed that when population density increases, health risks can increase as well.

Careers on the Case

Work Toward a Solution

The scientists who study populations often rely on others to gather or generate data, as well as to organize data properly. Statistics is the science of learning from data.

Statistician

Statisticians may work in teams with scientists from other fields. They may also work for businesses, government agencies, or the military. Many statisticians work to improve public health, protect the environment, or manage populations of wildlife.

VIDEO

Watch this video to learn about other careers in biology.

hhmi | BioInteractive

CHAPTER 5

STUDY GUIDE

Lesson Review

Go to your Biology Foundations Workbook for longer versions of these lesson summaries.

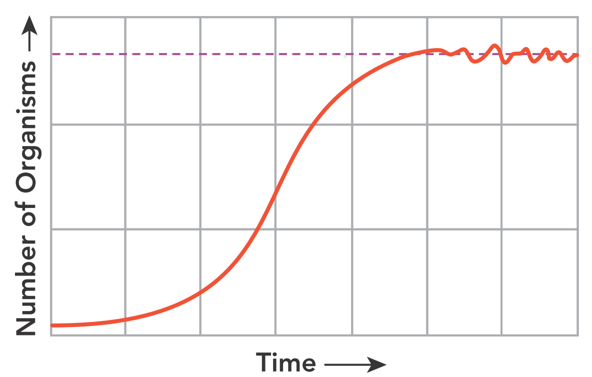
5.1 How Populations Grow

Ecologists study populations by examining their geographic range, growth rate, density and distribution, and age structure. For a population to increase, the number of births needs to exceed the number of deaths. Other factors affecting population growth are immigration and emigration.

A population will grow exponentially under ideal conditions with unlimited resources. Over time, though, this exponential growth will slow and eventually stop. The logistic S-shaped growth curve reflects this pattern. The maximum number of individuals of a particular species that a particular environment can support is its carrying capacity.

- population density
- population distribution
- age structure
- immigration
- emigration
- exponential growth
- logistic growth
- carrying capacity

Logistic Growth



Analyze Graphs At what point has this population reached its carrying capacity? How do you know?

5.2 Limits to Growth

The carrying capacity of a species in an environment is determined by limiting factors, which can be density dependent or density independent. Density-dependent limiting factors operate strongly when the population density reaches a certain level. The factors include competition, predation, herbivory, parasitism, disease, and stress from overcrowding.

Density-independent limiting factors affect all population sizes and densities. Density-independent factors including weather extremes such as hurricanes, droughts, or floods, and natural disasters such as wildfires may cause populations to crash. Human activities such as hunting and environmental degradation can also stress populations, sometimes leading to their extinction.

- limiting factor
- density-dependent limiting factor
- density-independent limiting factor

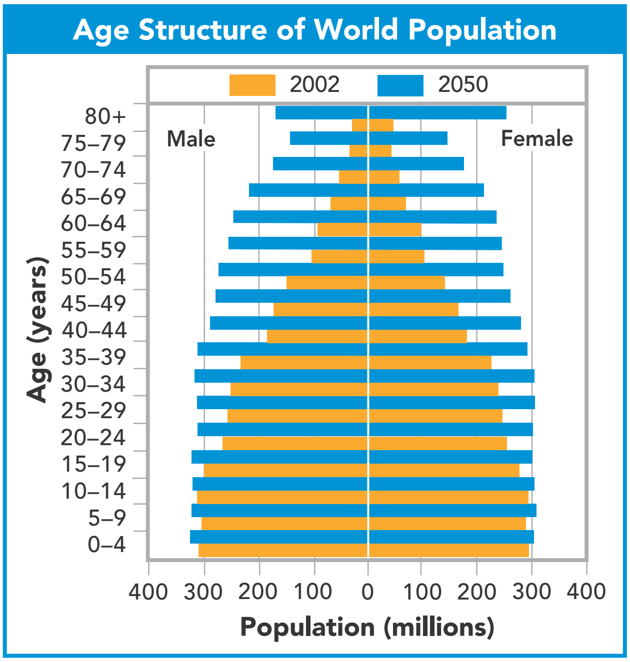
Classify Describe how each photo illustrates an example of a density-dependent or density-independent factor.

5.3 Human Population Growth

Human populations, like other populations, tend to increase. The rate of human population increases has changed over time. For most of human existence, our population grew slowly. Improvements in nutrition, sanitation, medicine, and public health in the 1800s led to a period of exponential growth, which continued into the mid-twentieth century. Although the growth rate has been slowly decreasing since then, the global population continues to grow.

Demography is the study of human populations and attempts to explain how those populations will change over time. Some countries have high growth rates, while others increase more slowly. Birthrates, death rates, and the age structure of a population can be used to make predictions about population growth rates. Some countries have reached a demographic transition, a dramatic change from high birthrates and death rates to low birthrates and death rates.

- demography
- demographic transition



Analyze Graphs Describe the changes in human population growth predicted by this figure. How do you think those changes will affect society?

Organize Information

List key details that support the main idea in each column.

What supports population growth?	What limits population growth?
1.	Competition
Immigration from other areas	2.
3.	4.
5.	6.

PERFORMANCE-BASED ASSESSMENT

A Tale of Two Countries
China and India

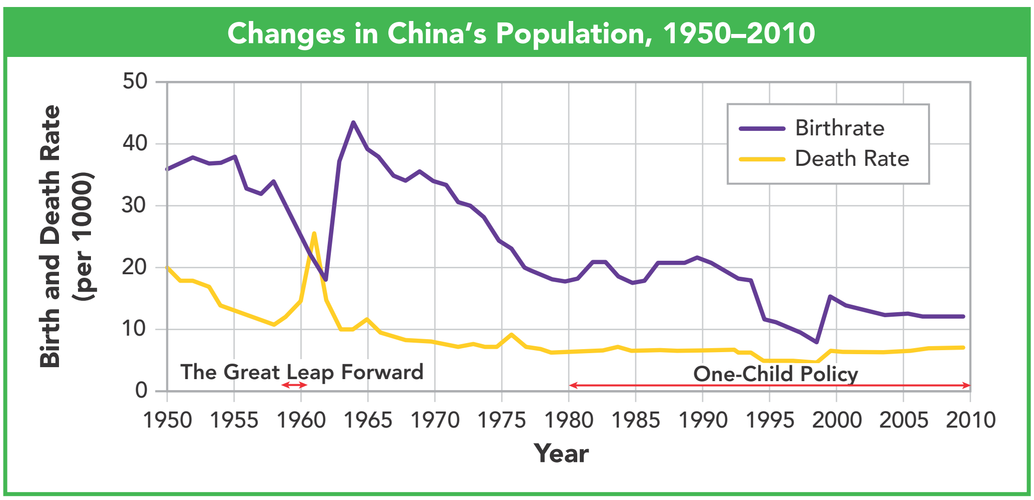
Analyze Data

HS-LS2-2, HS-LS2-7, CCSS.ELA-LITERACY.RST.9-10.3, CCSS.ELA-LITERACY.RST.9-10.7, CCSS.MATH.CONTENT.HSN.Q.A.1

STEM The line graph shows the birthrates and death rates in China from 1950 onward. The difference between the two rates shows how the population has changed each year. China's policies have had other effects, too. The age distribution of the population is very unusual, as shown by the age structure diagram on the next page. The shape reflects the changes in birthrates and death rates over time.

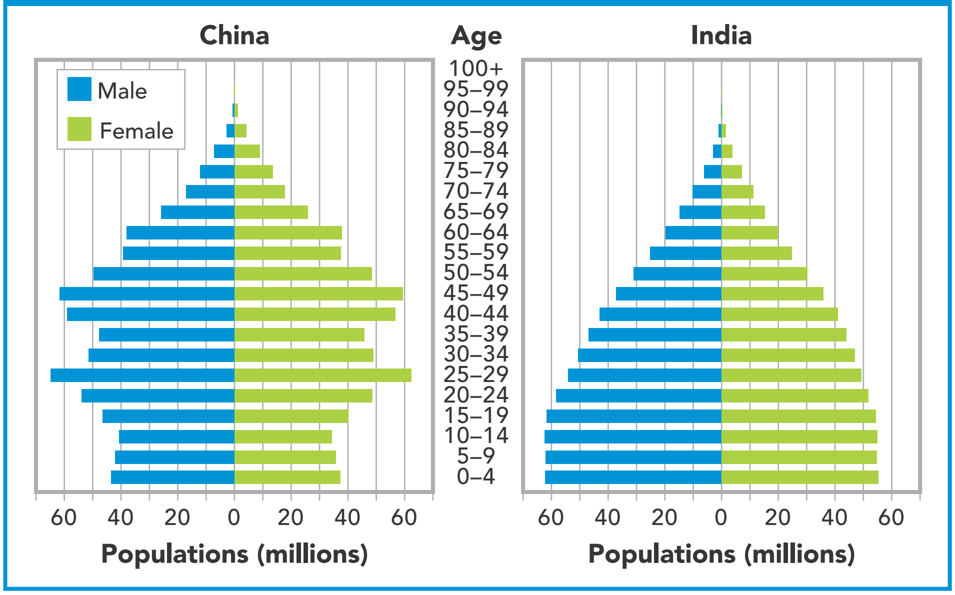
Another example to consider is India, which is the world's second most populous country after China. In fact, experts predict that India's population will overtake China by 2100. Unlike China, the government of India has not legislated laws to limit the size of families. Nevertheless, India faces problems that are similar to China's problems. Both countries have limited land for farming. If ocean levels rise due to global climate change, then much of the coastal farmland will be lost.

1. **Interpret Graphs** Use the line graph to determine the trend in China's population from 1950 onward.
2. **Conduct Research** Identify the factors that affect the human populations of China and India. Then, predict how these factors could affect their populations in the future.



Source: Our World in Data

Age and Sex Structure of China (2015) and India (2015)



Source: United Nations, *World Population Prospects*, 2006

3. **Construct an Explanation** Compare the age distributions of the populations of China and India. How do the government policies of the two countries help explain the differences you observe? Use evidence and logical reasoning to support the explanation you construct.

4. **Conduct Research** Choose one of the world's most populous countries, such as China, India, Nigeria, or the United States. Research how experts predict the population of the country will change over the next 50 to 100 years, and how people's lives will change as a result. Evaluate your sources for reliability, and cite the sources that provide the information you think is useful and accurate.

5. **Communicate** Organize and present your findings in the form of a poster, computer slide show, or written essay. Share your presentation with the class. Include these features:
   - A line graph or bar graph that shows the size of the population over time, including predictions for the future
   - An explanation for the predicted change in population
   - Likely effects of the change in population, including global effects

CHAPTER 5

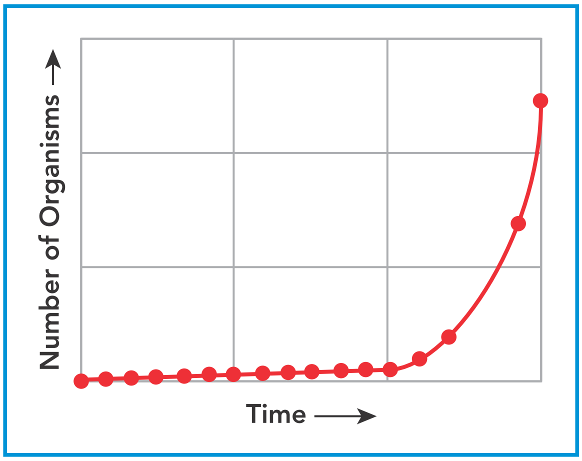
ASSESSMENT

KEY QUESTIONS AND TERMS

5.1 How Populations Grow

HS-LS2-1, HS-LS2-2

1. The primary factors affecting population growth include birthrate, death rate, immigration, and
   a. density.
   b. geographic range.
   c. emigration.
   d. demography.
2. Which factor might NOT contribute to an exponential growth rate in a given population?
   a. lower death rates
   b. higher birthrates
   c. less competition
   d. reduced resources
3. The graph shows a model of the growth of a bacterial population. Which of the following correctly describes the growth curve?
   a. demographic
   b. logistic
   c. limiting
   d. exponential



4. The maximum number of individuals of a particular species that a particular environment can support is its
   a. logistic growth.
   b. carrying capacity.
   c. age structure.
   d. population.
5. What are the phases of logistic growth?
6. What is the difference between immigration and emigration?
7. What is population density?
8. What are some examples of geographic range?

5.2 Limits to Growth

HS-LS2-1, HS-LS2-2, HS-LS2-6, HS-LS4-5

9. If a population grows larger than the carrying capacity of its environment, the
   a. death rate may rise.
   b. birthrate may rise.
   c. death rate must fall.
   d. birthrate must fall.
10. Which would be least likely to be affected by a density-dependent limiting factor?
    a. a small, scattered population
    b. a population with a high birthrate
    c. a large, dense population
    d. a population with a high immigration rate
11. Which of the following is a density-independent limiting factor?
    a. a struggle for food, water, space, or sunlight
    b. predator/prey relationships
    c. flood damage from a hurricane
    d. parasitism and disease
12. How might increasing the amount of a limiting nutrient in a pond affect the carrying capacity of the pond?
13. What are some limiting factors that contribute to a species' extinction?
14. Why is the rise-and-fall cycle of a predator-prey relationship an example of a density-dependent limiting factor?
15. What are some consequences of stress from overcrowding?
16. What human activities are examples of density-independent limiting factors?

5.3 Human Population Growth

HS-LS2-1, HS-LS2-2, HS-ESS3-1

17. The scientific study of human populations is called
    a. ecology.
    b. demography.
    c. natural selection.
    d. transition.

18. Since the Industrial Revolution, human populations have
  a. decreased.
  b. reached carrying capacity.
  c. grown more rapidly.
  d. leveled off.

19. Demographic transition refers to a shift from
  a. high birthrates and death rates to low birthrates and death rates.
  b. immigration to emigration.
  c. population decrease to population increase.
  d. logistic growth to exponential growth.

20. Much of the world's human population is growing exponentially because
  a. human populations have not reached their exponential curve.
  b. most countries have not yet completed the demographic transition.
  c. human populations do not conform to the logistic model.
  d. the food supply is limitless.

21. What were the limiting factors that Malthus identified as controls to human population increase?

22. How do age-structure diagrams predict the growth of a population?

23. How does population growth in the United States compare with that in Niger? (You may wish to refer to **Figure 5-15**.)

CRITICAL THINKING

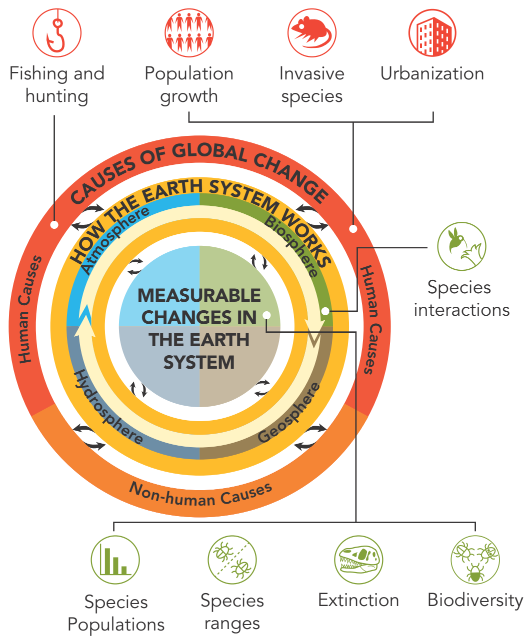
HS-LS2-1, HS-LS2-2

24. **Integrate Information** A scientist is studying a population of endangered Florida panthers. Why is the age structure of the population important to include in the study?

25. **Construct an Explanation** Asian carp were introduced to the lakes and rivers in the midwestern United States. They have no natural enemies there, and their population continues to increase. Use the concepts of birthrate and death rate to explain this population increase.

26. **Use Math** How can the size of a population continue to increase even as its rate of growth is decreasing? Assume that the increase in population is not due to immigration.

In this chapter, we have discussed how populations change over time. Use the diagram below to answer questions 27 and 28.



27. **Interpret Diagrams** Choose one human cause of global change. What Earth system processes and measurable changes are connected to that human activity? Explain at least three connections.

28. **Evaluate** How has hunting changed sea otter populations? How might changes in sea otter populations affect the kelp forest ecosystem? Make connections among the Understanding Global Change topics in your explanation. (*Hint:* Look back at the diagrams in Chapters 3 and 4, as well as the diagrams in this chapter.)

29. **Use Models** An aquarium is used to represent the population of fishes in a large lake. Describe one of the limiting factors that affects the fishes in the lake. Then, describe how the aquarium could model this factor.

30. **Classify** A fungus that attacks ears of corn can ruin a corn crop. Is the fungus an example of a density-dependent or density-independent limiting factor? Cite your reasoning in your answer.

31. **Apply Scientific Reasoning** Over the past 150 years, the world's human population has increased from 1 billion to more than 7 billion. Will this rate of increase continue over the next 150 years? Include evidence to support your answer.

CROSSCUTTING CONCEPTS

32. **Systems and System Models** Suppose all the wolves were removed from Isle Royale, leaving the moose with no natural predators. What would a graph of the moose population versus time look like? Explain your reasoning.

33. **Stability and Change** Why does exponential growth continue for only brief periods of time? Use the concepts of limiting factors and carrying capacity to construct your answer.

MATH CONNECTIONS

Analyze and Interpret Data

CCSS.MATH.CONTENT.HSN.Q.A.2

The data table shows the years when Earth's human population reached certain values. It also shows predictions for population size in the future. Use the data to answer questions 34–36.

World Population Milestones

Population (billion)	Year	Time Interval (year)
1	1804	—
2	1927	123
3	1960	33
4	1974	14
5	1987	13
6	1999	12
7	2012	13
8	2027	15
8.9	2050	23

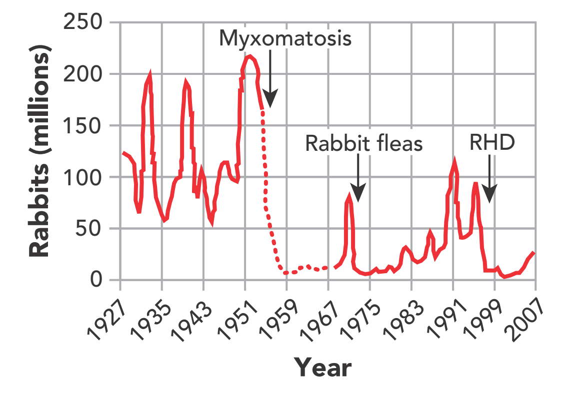
34. **Identify Patterns** Describe the pattern in world population growth shown by the data.

35. **Construct an Explanation** Based on your knowledge of human history and population science, propose an explanation for the pattern in the data you identified.

36. **Apply Scientific Reasoning** Do you think it is likely that the human population will ever increase at the same rate as it did from 1974 to 2012? Cite evidence and use logical reasoning to support your answer.

The graph shows the changing rabbit population in South Australia over many years. The points at which various population control measures were introduced are indicated. Use the graph to answer questions 37–39.

Rabbit Population Changes



37. **Interpret Graphs** Describe the changes to the rabbit population shown by the graph.

38. **Evaluate Data** How successful were each of the three measures used to control the rabbit population? Explain how the graph supports your answer.

39. **Predict** Assume that in 2020, myxomatosis is again introduced to the rabbit population. How do you predict the rabbit population will change as a result?

LANGUAGE ARTS CONNECTION

Write About Science

CCSS.ELA-LITERACY.WHST.9-10.2

40. **Write Informative Texts** Write a paragraph to explain the concept of the demographic transition, and to identify its three stages. Include references to **Figure 5-14** to illustrate your paragraph.

41. **Write Procedures** A science student is studying the growth of algae in a beaker of pond water. Write a procedure for the student to follow to investigate the limiting factors for the growth of the algae.

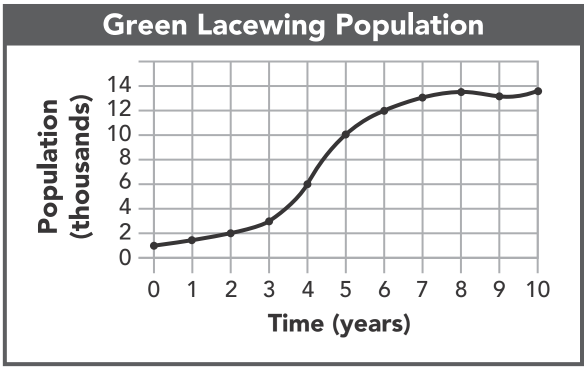
Read About Science

CCSS.ELA-LITERACY.RST.9-10.2

42. **Determine Central Ideas** How do factors that affect all plant and animal populations help explain the history of the human population? How do they help predict future changes?

END-OF-COURSE TEST PRACTICE

1. Green lacewings are used to control aphids, which are pests of many crops. A population of 1000 green lacewings is released into a farmer's field. The graph shows the change in the population over time.



What is the most likely explanation for the approximately constant population of the lacewings after the eighth year?

A. The lacewings had eaten all of the aphids in the field.
B. The lacewing population had reached the carrying capacity of the field.
C. New predators of lacewings had arrived in the field.
D. The birthrate of lacewings had increased, while the death rate remained constant.
E. The death rate of lacewings had increased, while the birthrate remained constant.

2. About 800 ash trees live in a tract of conservation land. Which of these events would have the LEAST effect on the land's carrying capacity for ash trees?

A. Maple trees are introduced to the land, where they grow well.
B. Human activities drain about half of the water that the land generally receives.
C. A beetle that infects ash trees is introduced to the land.
D. About one third of the ash trees are cut down and hauled away.
E. About one third of the land is cleared of all trees and used for new houses.

3. A lake is home to many native fishes and aquatic plants. Which of these events is most likely to threaten the biodiversity of the lake ecosystem?

A. A 20 percent increase in the population of one of the native fish species.
B. The arrival of migrating birds that prey on the native fishes.
C. The introduction of a nonnative fish species that has no natural enemies in the lake.
D. A storm that swells the lake and floods the surrounding land.
E. The arrival of winter weather that causes the water to freeze.

4. For many years in the 1800s, human hunters on the U.S. Great Plains hunted bison almost to extinction. Which statement, if true, best explains why the hunters were such a threat to the bison population?

A. The death rate from hunting was greater than the birthrate of the bison.
B. The death rate from hunting was greater than the natural death rate of the bison.
C. The hunting removed individuals of all ages, including very young bison.
D. Human hunters replaced the natural predators of the bison.
E. The hunting removed both male and female bison equally.

ASSESSMENT

For additional assessment practice, go online to access your digital course.

If You Have Trouble With...				
Question	1	2	3	4
See Lesson	5.1	5.2	5.2	5.2
Performance Expectation	HS-LS2-1	HS-LS2-1	HS-LS2-2	HS-LS2-2