

5.2 Limits to Growth

THINK ABOUT IT Now that you've seen *how* populations typically grow in nature, we can explore *why* they grow as they do. If populations tend to grow exponentially, why do they often follow logistic growth? In other words, what determines the carrying capacity of an environment for a particular species? Think again about hydrilla. In its native Asia, populations of hydrilla increase in size until they reach carrying capacity, and then population growth stops. But here in the United States, hydrilla grows out of control. The same is true of gypsy moths and many other introduced plant and animal species. Why does a species that is "well-behaved" in one environment grow out of control in another?



Key Questions

- What factors determine carrying capacity?
- What limiting factors depend on population density?
- What limiting factors do not typically depend on population density?

Vocabulary

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

Taking Notes

Outline Make an outline using the green and blue headings in this lesson. Fill in details as you read to help you organize the information.

Limiting Factors

What factors determine carrying capacity?

Recall that the productivity of an ecosystem can be controlled by a limiting nutrient. A limiting nutrient is an example of a general ecological concept: a limiting factor. In the context of populations, a **limiting factor** is a factor that controls the growth of a population.

As shown in **Figure 5–6**, there are several kinds of limiting factors. Some—such as competition, predation, parasitism, and disease—depend on population density. Others—including natural disasters and unusual weather—do not depend on population density. **Acting separately or together, limiting factors determine the carrying capacity of an environment for a species.** Limiting factors keep most natural populations somewhere between extinction and overrunning the planet.

Charles Darwin recognized the importance of limiting factors in shaping the history of life on Earth. As you will learn in Unit 5, the limiting factors we describe here produce the pressures of natural selection that stand at the heart of evolutionary theory.

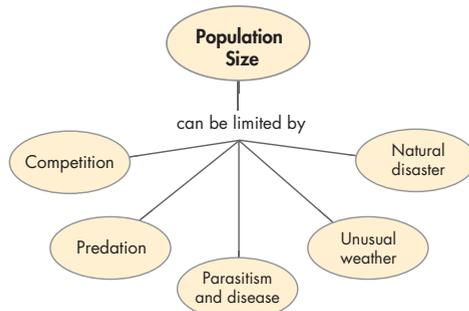


FIGURE 5–6 Limiting Factors Many different factors can limit population growth. Some of these factors depend on population density, while others do not. **Infer** How might each of these factors increase the death rate in a population?

Getting Started

Objectives

- 5.2.1 Identify** factors that determine carrying capacity.
- 5.2.2 Identify** the limiting factors that depend on population density.
- 5.2.3 Identify** the limiting factors that do not depend on population density.

Student Resources

- Study Workbooks A and B**, 5.2 Worksheets
- Spanish Study Workbook**, 5.2 Worksheets
- Lab Manual B**, 5.2 Hands-On Activity Worksheet

Lesson Overview • Lesson Notes • Activities: Art Review, InterActive Art • Assessment: Self-Test, Lesson Assessment

For corresponding lesson in the **Foundation Edition**, see pages 112–116.

Check understanding of limiting factors with **Art Review: Limiting Factors**.

Answers

FIGURE 5–6 Competition: organisms may not have enough resources to survive; Predation: organisms die when they are eaten; Parasitism and disease: organisms are killed; Natural disaster and unusual weather: organisms are killed or resources are diminished.



NATIONAL SCIENCE EDUCATION STANDARDS

UNIFYING CONCEPTS AND PROCESSES

I, III, IV

CONTENT

C.4.d, C.4.e, F.2

INQUIRY

A.1.b, A.2.a, A.2.d

Teach for Understanding

ENDURING UNDERSTANDING The existence of life on Earth depends on interactions among organisms and between organisms and their environment.

GUIDING QUESTION What factors limit a population's growth?

EVIDENCE OF UNDERSTANDING After completing the lesson, give students the following assessment to show their understanding of the factors that limit population growth. Have students make a **T-Chart** listing and describing limiting factors. One side of the T-chart should be labeled Density-Dependent Factors, and the other side labeled Density-Independent Factors.

Study Wkbks A/B, Appendix S30, T-Chart. **Transparencies**, GO15.

Teach

Lead a Discussion

Have students recall from the previous lesson the four factors that affect population growth. (*birthrate, immigration, death rate, emigration*)

Ask How can competition affect the birthrate of a population? (*If competition results in individuals not obtaining enough resources to reproduce, the birthrate of the population may decrease.*)

Ask How can competition affect the death rate of a population? (*If individuals cannot obtain enough resources to survive, the death rate may increase.*)

Ask How can competition affect the rates of immigration and emigration? (*If there is not much competition for the resources in an ecosystem, individuals from other ecosystems may move in, increasing immigration rate. If competition for resources is severe, the rate of emigration may increase as individuals seek other ecosystems in which to live.*)

DIFFERENTIATED INSTRUCTION

L1 Special Needs Help students summarize ways in which competition can affect birthrate, immigration, death rate, and emigration in simple sentences, for example, "Competition can reduce birthrate." Write each sentence on the board. Then, ask students to discuss details related to the main idea summarized in each of the sentences.



FIGURE 5-7 Competition Male wolves may fight one another for territory or access to mates.

Density-Dependent Limiting Factors

What limiting factors depend on population density?

Density-dependent limiting factors operate strongly only when population density—the number of organisms per unit area—reaches a certain level. These factors do not affect small, scattered populations as much. **Density-dependent limiting factors include competition, predation, herbivory, parasitism, disease, and stress from overcrowding.**

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

Competition is a density-dependent limiting factor, because the more individuals living in an area, the sooner they use up the available resources. Often, space and food are related to one another. Many grazing animals compete for territories in which to breed and raise offspring. Individuals that do not succeed in establishing a territory find no mates and cannot breed.

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

Predation and Herbivory The effects of predators on prey and the effects of herbivores on plants are two very 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 5-8** shows that populations of wolves and moose have **fluctuated** over the years. What drives these changes in population size?

Predator-Prey Relationships In a predator-prey relationship, populations of predators and prey may cycle up and down over time. Sometimes, the moose population on Isle Royale grows large enough that moose become easy prey for wolves. When wolves have plenty to eat, their population grows. As the wolf population grows, the wolves begin to kill more moose than are born. This causes the moose death rate to rise higher than its birthrate, so the moose population falls. As the moose population drops, wolves begin to starve. Starvation raises the wolves' death rate and lowers their birthrate, so the wolf population also falls. When only a few predators are left, the moose death rate drops, and the cycle repeats.

In Your Notebook Describe conditions that lead to competition in a population.

Quick Lab GUIDED INQUIRY

How Does Competition Affect Growth?

- 1 Label two paper cups 3 and 15. Make several small holes in the bottom of each cup. Fill each cup two-thirds full with potting soil. Plant 3 bean seeds in cup 3, and plant 15 bean seeds in cup 15.
- 2 Water both cups so that the soil is moist but not wet. Put them in a location that receives bright indirect light. Water the cups equally as needed.
- 3 Count the seedlings every other day for two weeks.

Analyze and Conclude

1. **Observe** What differences did you observe between the two cups?

Quick Lab

PURPOSE Students will be able to determine that competition affects plant growth.

MATERIALS bean seeds, 2 paper cups, potting soil, waterproof marker

SAFETY Students should wash their hands after planting the seeds.

PLANNING You may want to provide a tray or other waterproof surface on which students can place their cups. Remind them to control variables such as the amount of water and amount of sunlight the cups of seeds receive.

ANALYZE AND CONCLUDE

1. The seedlings in cup 15 will be smaller and less robust than those in cup 3. Some seedlings in cup 15 may die.

Answers

IN YOUR NOTEBOOK When populations become crowded, individuals compete for resources.



Use Visuals

Have students examine **Figure 5–8** to help them understand the effects of predator-prey relationships on population size.

Ask What general trends are shown in this graph? (*An increase in the wolf population is usually accompanied by a decrease in the moose population. A decrease in the wolf population is usually accompanied by an increase in the moose population.*)

Ask What factors other than the predator-prey relationship affected the size of these populations during the time period represented in the graph? (*disease, the moose's changing food supply*)

DIFFERENTIATED INSTRUCTION

L1 Struggling Students Make sure students understand that two separate sets of data are plotted on the graph. Point out the left and right vertical axes, which are numbered in different increments. Explain that the left vertical axis and the blue line represent the wolf population; the right vertical axis and the red line represent the moose population.

L3 Advanced Students Have students work in a group to discuss trends they might expect to have occurred in the balsam fir population on Isle Royale over the time period represented in the graph. Ask them to share a brief summary of their discussion with the class.

ELL Focus on ELL: Build Background

ALL SPEAKERS Have students use the **Think-Pair-Share** strategy to help them more fully comprehend density-dependent limiting factors. Pair beginning and intermediate speakers with advanced or advanced high speakers. Have students read the information about density-dependent limiting factors one factor at a time. After they read, suggest they discuss the factor and try to identify an example of it that they may have either seen or read about in the past. For example, for herbivory, some students may have seen an insect eating a plant leaf. Have pairs write down their examples and then share them with the class.

Study Wkbks A/B, Appendix S14, Think-Pair-Share.



Have students explore how predation can affect population growth in **InterActive Art: Moose-Wolf Populations on Isle Royale**.

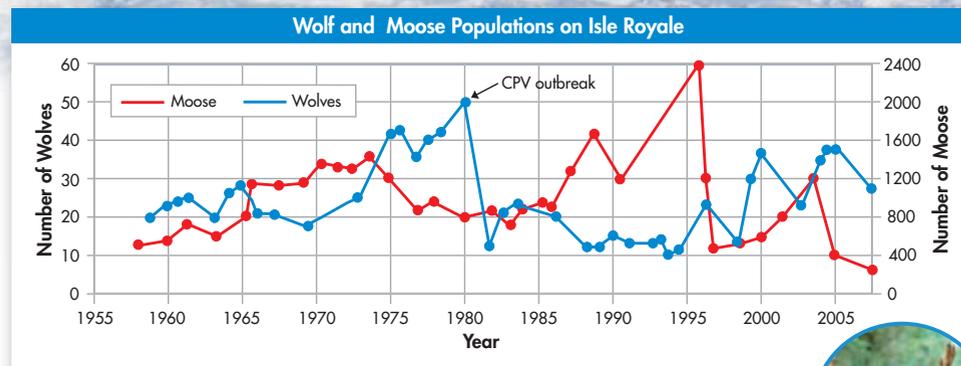


FIGURE 5–8 Moose-Wolf Populations on Isle Royale

The relationship between moose and wolves on Isle Royale illustrates how predation can affect population growth. In this case, the moose population was also affected by changes in food supply, and the wolf population was also impacted by a canine parvovirus (CPV) outbreak.



► **Herbivore Effects** Herbivory can also contribute to changes in population numbers. 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, the moose may suffer from lack of food.

► **Humans as Predators** In some situations, human activity limits populations. For example, humans are major predators of codfish in New England. Fishing fleets, by catching more and more fish every year, have raised cod death rates so high that birthrates cannot keep up. As a result, the cod population has been dropping. Is there any way to solve the problem? Think of predator-prey interactions. The cod population can recover if we scale back fishing to lower the death rate sufficiently. Biologists are studying birthrates and the age structure of the cod population to determine how many fish can be taken without threatening the survival of the population.

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 irregularly.

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How Science Works

RESEARCH ON ISLE ROYALE

Isle Royale, an island in Lake Superior, is a National Park that has been the site of research on the interactions of wolf and moose populations for more than 50 years. It is considered an ideal site for research in the field of population biology because of its isolation. Wolves first moved into the Isle Royale ecosystem in the 1940s via an ice bridge. In the late 1950s, scientists began studying the interactions of the populations of moose and wolves; the study continues today. The long-term nature of the study has allowed scientists to learn not only about direct effects of predator-prey interactions on populations, but also to examine the impact of other factors affecting populations, such as changing pollution levels and environmental legislation.

Teach continued

Build Study Skills

Have students use a **Venn Diagram** to compare and contrast limiting factors. They should use one side to record facts about density-dependent limiting factors and the other side to record facts about density-independent limiting factors. Have them record information applying to both density-dependent and density-independent factors in the middle section.

Study Wkbks A/B, Appendix S33, Venn Diagram. **Transparencies**, GO18.

DIFFERENTIATED INSTRUCTION

L1 Struggling Students Have students make a drawing of a population being affected by a limiting factor. Tell them to make their drawing both creative and scientifically accurate. Instruct students to write a caption for their drawing. Captions should be at least two sentences long and identify the limiting factor depicted in the drawing. It should also categorize the limiting factor as either density-dependent or density-independent, and describe how the limiting factor affects the population shown.

ELL English Language Learners Write the terms *density-independent* and *density-dependent* on the board. Have students locate the definitions of these terms in the text. Then, ask students to write or state a definition for each term in their own words.



Students should identify limiting factors, such as competition, predation, parasitism and disease, overcrowding, severe weather, and natural disasters. Students can go online to Biology.com to gather their evidence.



FIGURE 5-9 Parasitism The ticks feeding on the blood of this hedgehog can transmit bacteria that cause disease.

Parasitism and Disease Parasites and disease-causing organisms feed at the expense of their hosts, weakening them and often causing disease or death. The ticks on the hedgehog in **Figure 5-9**, for example, can carry diseases. Parasitism and disease are density-dependent effects because the denser the host population, the more easily parasites can spread from one host to another.

If you look back at the graph in **Figure 5-8**, you can see a sudden and dramatic drop in the wolf population around 1980. At that time, a viral disease of wolves was accidentally introduced to the island. This virus killed all but 13 wolves on the island—and only three of the survivors were females. The removal of wolves caused moose populations to skyrocket to 2400. The densely packed moose then became infested with winter ticks that caused hair loss and weakness.

Stress From Overcrowding Some species fight amongst themselves if overcrowded. Too much fighting can cause high levels of stress, which can weaken the body’s ability to resist disease. In some species, stress from overcrowding can cause females to neglect, kill, or even eat their own offspring. Thus, stress from overcrowding can lower birthrates, raise death rates, or both. It can also increase rates of emigration.

Density-Independent Limiting Factors

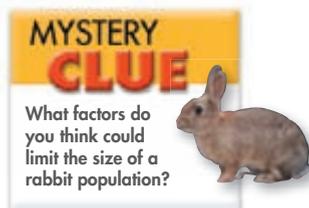
What limiting factors do not typically depend on population density?

Density-independent limiting factors affect all populations in similar ways, regardless of population size and density.

Unusual weather 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.

For some species, storms can nearly extinguish local populations. For example, thrips, aphids, and other insects that feed on leaves can be washed out by a heavy rainstorm. Waves whipped up by hurricanes can devastate shallow coral reefs. Extremes of cold or hot weather also can take their toll, regardless of population density. A severe drought, for example, can kill off great numbers of fish in a river, as shown in **Figure 5-10**.

True Density Independence? Sometimes, however, the effects of so-called density-independent factors can 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 the moose to move around to find food.



Ubd Check for Understanding

VISUAL REPRESENTATION

Ask students to create a **Concept Map** showing how limiting factors affect populations.

Study Wkbks A/B, Appendix S21, Concept Map. **Transparencies**, GO4.

ADJUST INSTRUCTION

If students’ concept maps reveal they are struggling to understand limiting factors, ask them to review their concept maps in small groups. Within each group, have students review and revise their concept maps.

Because this was an island population, emigration was not possible; the moose weakened and many died. So, in this case, the effects of bad weather on the large, dense population were greater than they would have been on a small population. (In a smaller population, the moose would have had more food available because there would have been less competition.) This situation shows that it is sometimes difficult to say that a limiting factor acts *only* in a density-independent way.

Human activities can also place ecological communities under stress in ways that can hamper a population's ability to recover from natural disturbance. You will learn more about that situation in the next chapter.

Controlling Introduced Species In hydrilla's natural environment, density-dependent population limiting factors keep it under control. Perhaps plant-eating insects or fishes devour it. Or perhaps pests or diseases weaken it. Whatever the case, those limiting factors are not found in the United States. The result is runaway population growth!

Efforts at artificial density-independent control measures—such as herbicides and mechanical removal—offer only temporary solutions and are expensive. Researchers have spent decades looking for natural predators and pests of hydrilla. The best means of control so far seems to be an imported fish called grass carp, which view hydrilla as an especially tasty treat. These grass carp are not native to the United States. Only sterilized grass carp can be used to control hydrilla. Can you understand why?



FIGURE 5-10 Effects of a Severe Drought on a Population Dead fish lie rotting on the banks of the once-flowing Paraná de Manaquiri River in Brazil.

Build Science Skills

Have students study **Figure 5-10**. Then, ask them to make inferences about the impact of the drought on a variety of populations in this ecosystem. For example, a population of water plants might become overcrowded as a result of a decrease in the water level of the river. Or, plants along the riverbank might dry out and die, limiting nesting places for some birds. Have volunteers discuss their inferences with the class.

DIFFERENTIATED INSTRUCTION

L1 Struggling Students Provide students with a few examples of how the drought pictured in **Figure 5-10** might have affected populations in the ecosystem. Then, have them work in pairs to identify additional examples.

Assess and Remediate

EVALUATE UNDERSTANDING

Name a type of ecosystem, such as forest, pond, or grassland. Have a volunteer identify one population of living things typically found in that ecosystem. Then, ask volunteers to describe as many specific limiting factors affecting the population as possible. As each limiting factor is identified, have students categorize it as density-dependent or density-independent. Then, have students complete the 5.2 Assessment.

REMEDICATION SUGGESTION

L1 Struggling Students Have students work in small groups to brainstorm a list of specific density-independent limiting factors if they are struggling to answer **Question 3b**.

BIOLOGY.com Students can check their understanding of lesson concepts with the **Self-Test** assessment. They can then take an online version of the **Lesson Assessment**.

5.2 Assessment

Review Key Concepts

- a. Review** What is a limiting factor?

b. Apply Concepts How do limiting factors affect the growth of populations?
- a. Review** List three density-dependent limiting factors.

b. Relate Cause and Effect What is the relationship between competition and population size?
- a. Review** What is a density-independent limiting factor?

b. Apply Concepts Give three examples of density-independent factors that could severely limit the growth of a population of bats living in a cave.

Apply the Big idea

Interdependence in Nature

- Study the factors that limit population growth shown in **Figure 5-6**. Classify each factor as biotic or abiotic. (*Hint: Refer to Lesson 3.1 for information on biotic and abiotic factors.*)

BIOLOGY.com Search Lesson 5.2 GO Self-Test Lesson Assessment

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Assessment Answers

- 1a.** a factor that controls the growth of a population

1b. by determining the carrying capacity of environments for populations
- 2a.** Answers may vary: Factors include competition, predation, herbivory, parasitism, disease, stress from overcrowding.

2b. Competition between individuals increases as population size increases.
- 3a.** a factor that affects populations regardless of their size or density

3b. Sample answer: A drought could limit food supplies outside the cave. A flood could fill the cave with water. A snowstorm could block the entrance to the cave.
- 4.** **Big idea** Biotic factors include competition, predation, and parasitism and disease. Unusual weather and natural disasters are abiotic factors.