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.

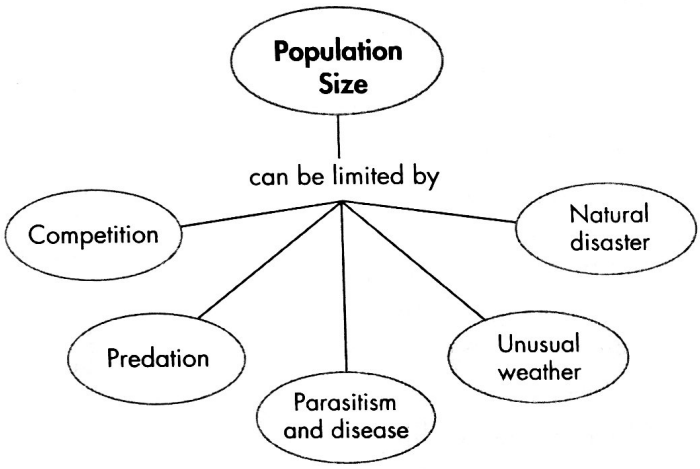


FIGURE 5–6 Limiting Factors Many different factors can limit population growth. Some of these factors depend on population density, while others do not. **Infer** ***How might each of these factors increase the death rate in a population?***

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

Quick Lab GUIDED INQUIRY

How Does Competition Affect Growth?

❶ 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.

❷ 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.

❸ Count the seedlings every other day for two weeks.

Analyze and Conclude

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

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.*

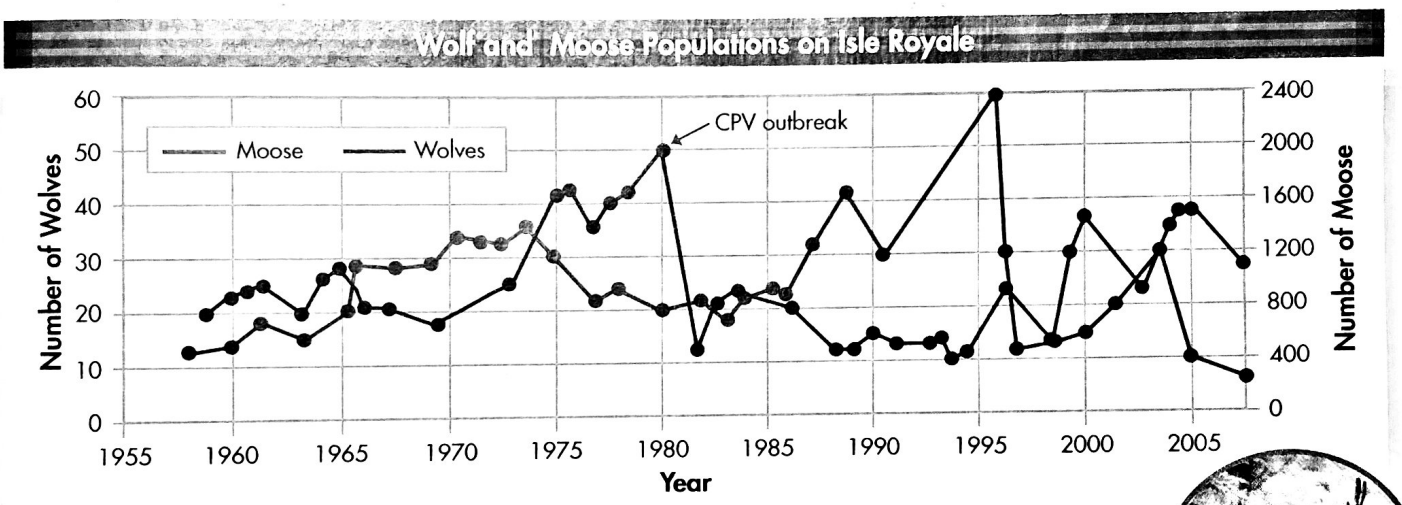


FIGURE 5–8 Moose-Wolf Populations on Isle Royale The relationship between moose and wolves on Isle Royale illustrates how predation can affect population growth. In this case, the moose population was also affected by changes in food supply, and the wolf population was also impacted by a canine parvovirus (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.

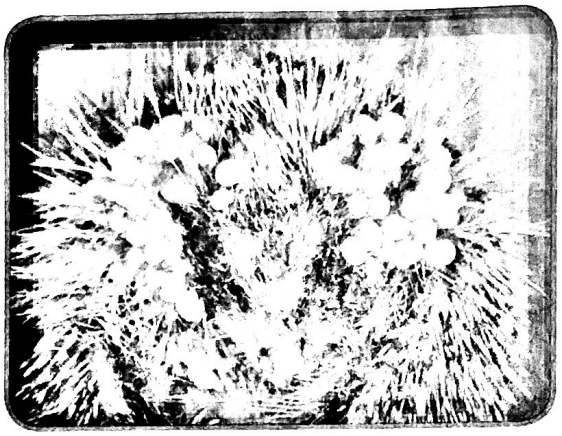


FIGURE 5–9 Parasitism The ticks feeding on the blood of this hedgehog can transmit bacteria that cause disease.

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

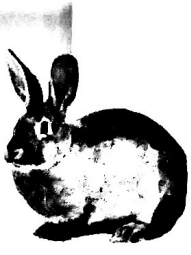
What limiting factors do not typically depend on population density?

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.

MYSTERY CLUE



What factors do you think could limit the size of a rabbit population?

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.

5.2 Assessment

Review Key Concepts

1. a. Review What is a limiting factor?

b. Apply Concepts How do limiting factors affect the growth of populations?

2. a. Review List three density-dependent limiting factors.

b. Relate Cause and Effect What is the relationship between competition and population size?

3. 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

4. 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.)