POPULATIONS

CHAPTER 8
Understanding Populations

CHAPTER 9
The Human Population

CHAPTER 10
Biodiversity

This school of young striped cat-fish near the coast of Australia gathers into a huge, writhing ball to defend against predators. Forming a ball makes the fish look like one large organism, and the fish's stripes may make it hard for a predator to see individual fish.

195

Understanding Populations

1 How Populations Change in Size

2 How Species Interact with Each Other

READING WARM-UP

Before you read this chapter, take a few minutes to answer the following questions in your *EcoLog.*

1. What might cause the number of organisms in a group to increase or decrease?

2. What are some different ways that two species could affect each other?

Orcas (also called killer whales) hunt sea lions. The interaction between these groups affects the number of individuals and the behavior of individuals in each group.

How Populations Change in Size

Biologist Charles Darwin once calculated that a single pair of elephants could theoretically produce 19 million descendants within 750 years. Darwin made the point that the actual number of elephants is limited by their environment.

One way to study the relationship of elephants with their environment is at the level of populations. Such a study would include tracking the number of elephants in an area and observing the animals' interactions with their environment.

What Is a Population?

A **population** is all the members of a species living in the same place at the same time. The bass in an Iowa lake make up one population. **Figure 1** shows other examples of populations. A population is a reproductive group because organisms usually breed with members of their own population. For example, daisies in an Ohio field will breed with each other and not with daisies in a Maryland population. The word *population* refers to the group in general and also to the size of the population—the number of individuals it contains.

Objectives

▶ **Describe** the three main properties of a population.

▶ **Describe** exponential population growth.

▶ **Describe** how the reproductive behavior of individuals can affect the growth rate of their population.

▶ **Explain** how population sizes in nature are regulated.

Key Terms

population
density
dispersion
growth rate
reproductive potential
exponential growth
carrying capacity

Figure 1 ▶ The palm trees on an island (left) and a school of fish (below) are examples of populations.

Figure 2 ▶ Populations may have very different sizes, densities, and dispersions. Flamingos (right) are usually found in huge, dense flocks, while most snakes (above) are solitary and dispersed randomly.

QuickLAB

Population Growth

Procedure

1. Model the change in size of a population by applying the equation at right.
2. Start with **100 g (3.5 oz) of dry beans**. Count out five beans to represent the starting population of a species.
3. Assume that each year 20 percent of the beans each have two offspring. Also assume that 20 percent of the beans die each year.
4. Calculate the number of beans to add or subtract for 1 y. Round your calculations to whole numbers. Add to or remove beans from your population as appropriate.
5. Continue modeling your population changes over the course of 10 y. Record each change.

Analysis

1. Make a graph of your data. Describe the changes in your population.

Properties of Populations

Populations may be described in terms of size, density, or dispersion, as shown in **Figure 2.** A population's **density** is the number of individuals per unit area or volume, such as the number of bass per cubic meter of water in a lake. A population's **dispersion** is the relative distribution or arrangement of its individuals within a given amount of space. A population's dispersion may be *even, clumped,* or *random*. Size, density, dispersion, and other properties can be used to describe populations and to predict changes within them.

How Does a Population Grow?

A population gains individuals with each new offspring or birth and loses them with each death. The resulting population change over time can be represented by the equation below. A change in the size of a population over a given period of time is that population's **growth rate.** The growth rate is the *birth rate* minus the *death rate*.

Over time, the growth rates of populations change because birth rates and death rates increase or decrease. Growth rates can be positive, negative, or zero. For a population's growth rate to be zero, the average number of births must equal the average number of deaths. A population would remain the same size if each pair of adults produced exactly two offspring, and each of those offspring survived to reproduce. If the adults in a population are not replaced by new births, the growth rate will be negative and the population will shrink.

How Fast Can a Population Grow?

A female sea turtle may lay 2,000 eggs in her lifetime in nests she digs in the sand. **Figure 3** shows newly hatched sea turtles leaving their nest for the ocean. If all of them survived, the turtle population would grow rapidly. But they do not all survive. Populations usually stay about the same size from year to year because various factors kill many individuals before they can reproduce. These factors control the sizes of populations. In the long run, the factors also determine how the population evolves.

Reproductive Potential A species' *biotic potential* is the fastest rate at which its populations can grow. This rate is limited by the maximum number of offspring that each member of the population can produce, which is called its reproductive potential. Some species have much higher reproductive potentials than others. Darwin calculated that it could take 750 years for a pair of elephants to produce 19 million descendants. In contrast, a bacterium can produce 19 million descendants in a few days or weeks.

Reproductive potential increases when individuals produce more offspring at a time, reproduce more often, and reproduce earlier in life. Reproducing earlier in life has the greatest effect on reproductive potential. Reproducing early shortens the *generation time,* the average time it takes a member of the population to reach the age when it reproduces.

Small organisms, such as bacteria and insects, have short generation times. These organisms can reproduce when they are only a few hours or a few days old. As a result, their populations can grow quickly. In contrast, large organisms, such as elephants and humans, become sexually mature after a number of years. The human generation time is about 20 years, so humans have a much lower reproductive potential than insects.

Exponential Growth Populations sometimes undergo exponential growth, which means they grow faster and faster. For example, if a pair of dogs gives birth to 6 puppies, there will be 6 dogs in one generation. If each pair of dogs in that generation has 6 puppies, there will be 18 dogs in the next generation. The following generation will contain 54 dogs, and so on. If the number of dogs is plotted versus time on a graph, the graph will have the shape shown in **Figure 4.** In exponential growth, a larger number of individuals is added to the population in each succeeding time period.

Exponential growth occurs in nature only when populations have plenty of food and space, and have no competition or predators. For example, populations of European dandelions and starlings imported into the United States underwent exponential growth. Similar population explosions occur when bacteria or molds grow on a new source of food.

Figure 3 ▶ Most organisms have a reproductive potential that far exceeds the number of their offspring that will survive. Very few of these baby sea turtles will survive long enough to breed.
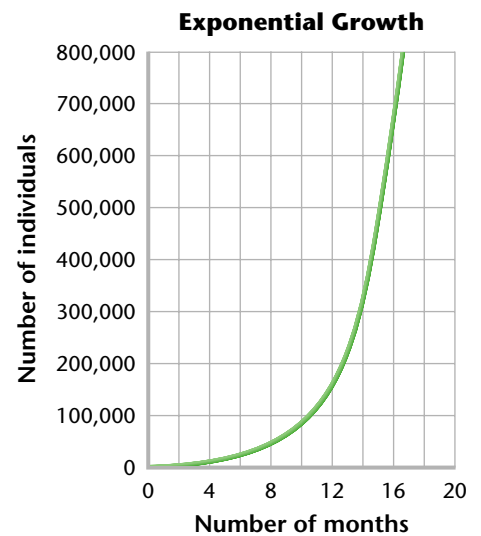

Figure 4 ▶ Population growth is graphed by plotting population size over a period of time. Exponential population growth will look like the curve shown here.

Ecofact

Carrying Capacity of Islands
Islands are good places to study carrying capacity because islands have clear boundaries. The Pribilof Islands near Alaska were the site of a well-studied population explosion and crash. In 1911, 25 reindeer were introduced on one of the islands. By 1938, the herd had grown to 2,000 animals. The reindeer ate mostly lichens, which grow back very slowly. By 1950, there were only 8 reindeer alive on the island.

Figure 5 ▶ An example of carrying capacity is shown by the dashed yellow line in the graph (right). This line seems to be a limit on the size of the example population (blue line). When rabbits were introduced into Australia (below), their population quickly exceeded the carrying capacity of the area.
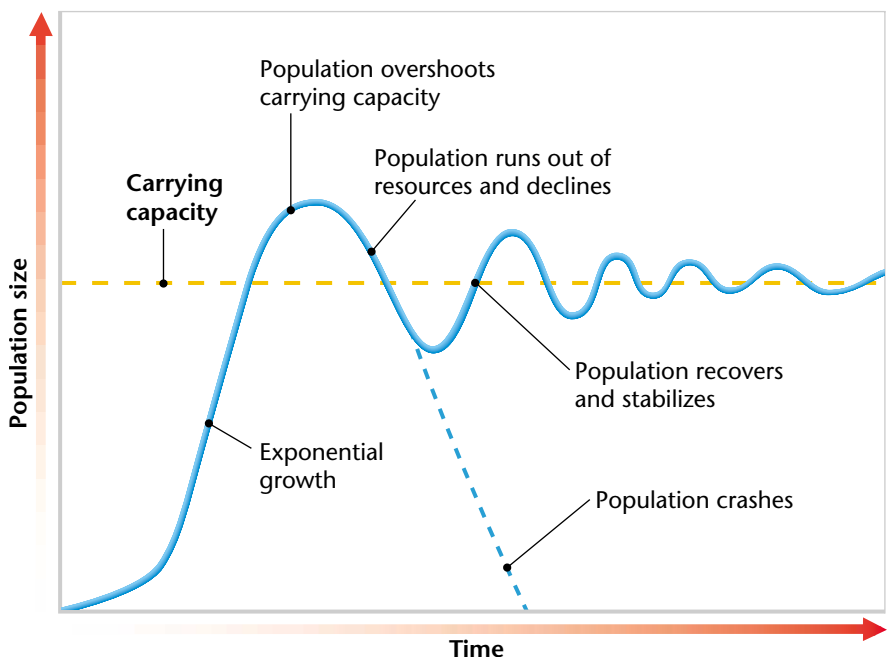

What Limits Population Growth?

Because natural conditions are neither ideal nor constant, populations cannot grow forever and rarely grow at their reproductive potential. Eventually, resources are used up or the environment changes, and deaths increase or births decrease. Under the forces of natural selection in a given environment, only some members of any population will survive and reproduce. Thus, the properties of a population may change over time.

Carrying Capacity   The blue line in **Figure 5** represents a population that seems to be limited to a particular size. This theoretical limit, shown by the dashed yellow line, is called *carrying capacity*. The carrying capacity of an ecosystem for a particular species is the maximum population that the ecosystem can support indefinitely. A population may increase beyond this number, but it cannot stay at this increased size. Because ecosystems change, carrying capacity is difficult to predict or calculate exactly. However, carrying capacity may be estimated by looking at average population sizes or by observing a population crash after a certain size has been exceeded.

The history of rabbits in Australia demonstrates both exponential growth and carrying capacity. Originally, there were no rabbits in the native ecosystems of Australia. When rabbits were introduced there in 1859, their numbers increased rapidly because they had plenty of vegetation to eat, no competition, and no predators. But eventually, disease and starvation caused the rabbit population to crash. Over time, the vegetation recovered, and the rabbit population increased again. The population continues to increase and decrease, but less dramatically.

Population overshoots carrying capacity

Population runs out of resources and declines

Carrying capacity

Population recovers and stabilizes

Exponential growth

Population crashes

Population size

Time

Resource Limits A species reaches its carrying capacity when it consumes a particular natural resource at the same rate at which the ecosystem produces the resource. That natural resource is then called a *limiting resource* for the species in that area. For example, plant growth is limited by supplies of water, sunlight, and mineral nutrients. The supply of the most severely limited resources determines the carrying capacity of an environment for a particular species at a particular time.

Competition Within a Population The members of a population use the same resources in the same ways, so they will eventually compete with one another as the population approaches its carrying capacity. An example is the fate of mealworm larvae in a sack of flour. Adults of this type of beetle will find a sack of flour, lay their eggs in the sack, and leave. Most of the first larvae to hatch will have plenty of flour to eat and will grow to adulthood. However, the sack has a limited amount of food, and mealworms from eggs that were laid later may not have enough food to survive to adulthood.

Instead of competing directly for a limiting resource, members of a species may compete indirectly for social dominance or for a territory. A *territory* is an area defended by one or more individuals against other individuals. The territory is of value not only for the space but also for the shelter, food, or breeding sites it contains. Competition within a population is part of the pressure of natural selection. Many organisms expend a large amount of time and energy competing with members of the same species for mates, food, or homes for their families. Some examples of competition within species are shown in **Figure 6.**

Figure 6 ▶ Members of a population often compete with each other. These plants (above) are growing over each other as they compete for light. These wolves (left) are competing for food and for social dominance.

MATH PRACTICE

Growth Rate A growth rate is a change in a population's size over a specific period of time.

$$\frac{growth}{rate} = \frac{change\ in\ population}{time}$$

Imagine a starting population of 100 individuals. If there were 10 births and 5 deaths in a given year, what was the population's growth rate for the year? In the next year, if there were 20 births and 10 deaths, what would the new growth rate be? If births increased by 10 and deaths increased by 5 for each of the next 5 years, how would you describe the growth of this population?

Figure 7 ▶ The way a disease spreads through a population is affected by the population's density. These pine trees have been infected by a disease carried by the southern pine beetle. This disease has spread rapidly through U.S. timber forests.

Connection to **History**

Density and Disease The black plague of 14th-century Europe was spread in a density-dependent pattern. About one-third of Europe's population died from the highly contagious disease. Most of the deaths occurred in the crowded towns of the time, and fewer deaths occurred in the countryside.

Figure 8 ▶ Weather events usually affect every individual in a similar way, so such events are considered density-independent regulation.

Two Types of Population Regulation

Population size can be limited in ways that may or may not depend on the density of the population. Causes of death in a population may be *density dependent* or *density independent*.

When a cause of death in a population is *density dependent*, deaths occur more quickly in a crowded population than in a sparse population. This type of regulation happens when individuals of a population are densely packed together, such as when a population is growing rapidly. Limited resources, predation, and disease result in higher rates of death in dense populations than in sparse populations. The pine trees in **Figure 7** are infected with a disease that is spreading in a density-dependent pattern. Many of the same kind of pine tree are growing close to each other, so a disease-carrying beetle easily spreads the disease from one tree to another.

When a cause of death is *density independent*, a certain proportion of a population may die regardless of the population's density. This type of regulation affects all populations in a general or uniform way. Severe weather and natural disasters are often density-independent causes of death. The winter storm shown in **Figure 8** froze crops and fruiting trees regardless of the density of plants in the area.

SECTION 1 **Review**

1. **Compare** two populations in terms of size, density, and dispersion. Choose any populations you know of.

2. **Describe** exponential population growth.

3. **Describe** three methods by which the reproductive behavior of individuals can affect the growth rate of a population.

4. **Explain** how population sizes in nature are regulated.

CRITICAL THINKING

5. **Making Predictions** How accurately do you think the size of a population can be predicted? What information might be needed to make this prediction?

6. **Compare and Contrast** Read the description of the populations of rabbits in Australia and reindeer in the Pribilof Islands. List the similarities and differences between these two histories. **READING SKILLS**