Section 2

Integrating Mathematics

Studying Populations

Reading Preview

Key Concepts

- How do ecologists determine the size of a population?
- What causes populations to change in size?
- What factors limit population growth?

Key Terms

- estimate
- birth rate
- death rate
- immigration
- emigration
- population density
- limiting factor
- carrying capacity

Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a question for each heading. As you read, write the answers to your questions.

Studying Populations

Question	Answer
How do you determine population size?	Some methods of determining population size are . . .

Lab zone Discover Activity

What's the Population of Beans in a Jar?

1. Fill a plastic jar with dried beans. This is your model population.
2. Your goal is to determine the bean population size, but you will not have time to count every bean. You may use any of the following to help you: a ruler, a small beaker, another large jar. Set a timer for two minutes when you are ready to begin.
3. After two minutes, record your answer. Then count the beans. How close was your answer?

Think It Over

Forming Operational Definitions In this activity, you came up with an estimate of the size of the bean population. Write a definition of the term *estimate* based on what you did.

How would you like to be an ecologist today? Your assignment is to study the albatross population on an island. One question you might ask is how the size of the albatross population has changed over time. Is the number of albatrosses on the island more than, less than, or the same as it was 50 years ago? To answer this question, you must first determine the current size of the albatross population.

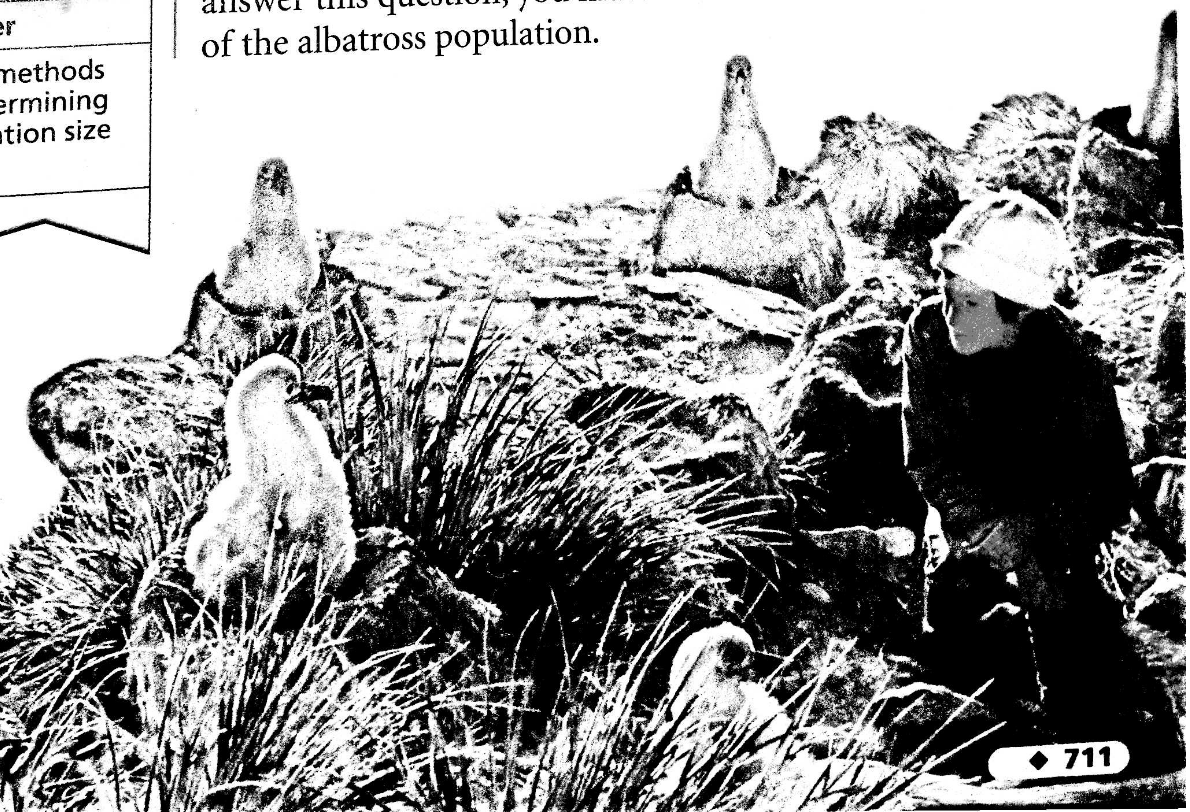


FIGURE 5
Studying Populations
These young albatrosses are part of a larger albatross population in the Falkland Islands.

Determining Population Size

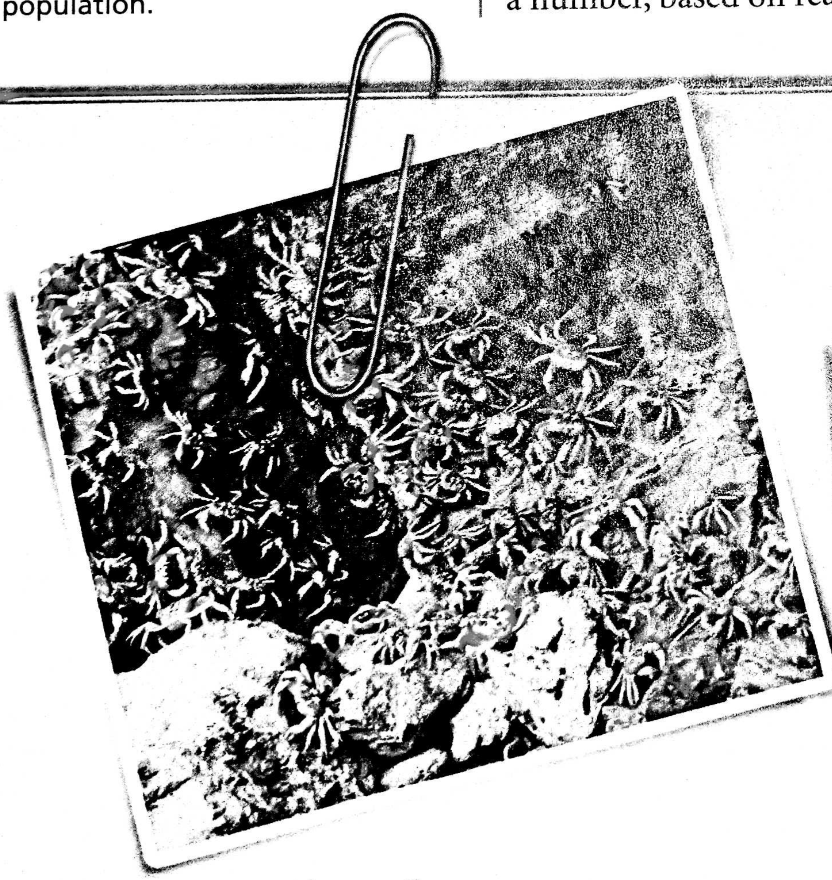
Some methods of determining the size of a population are direct and indirect observations, sampling, and mark-and-recapture studies.

Direct Observation The most obvious way to determine the size of a population is to count all of its members. For example, you could try to count all the crabs in a tide pool.

Indirect Observation Sometimes it may be easier to observe signs of organisms rather than the organisms themselves. Look at the mud nests built by cliff swallows in Figure 6. Each nest has one entrance hole. By counting the entrance holes, you can determine the number of swallow nests in this area. Suppose that the average number of swallows per nest is four: two parents and two offspring. If there are 120 nests, you can multiply 120 by 4 to determine that there are 480 swallows.

Sampling In many cases, it is not even possible to count signs of every member of a population. The population may be very large or spread over a wide area. In such cases, ecologists usually make an estimate. An **estimate** is an approximation of a number, based on reasonable assumptions.

FIGURE 6
Determining Population Size
Scientists use a variety of methods to determine the size of a population.



Direct Observation
Counting these crabs one by one is an example of direct observation.

Indirect Observation
One way to determine this cliff swallow population is to count their cone-shaped nests.

One way to estimate the size of a population is to count the number of organisms in a small area (a sample), and then multiply to find the number in a larger area. To get the most accurate estimate, your sample area should be typical of the larger area. Suppose you count 8 birch trees in 100 square meters of a forest. If the entire forest were 100 times that size, you would multiply your count by 100 to estimate the total population, or 800 birch trees.

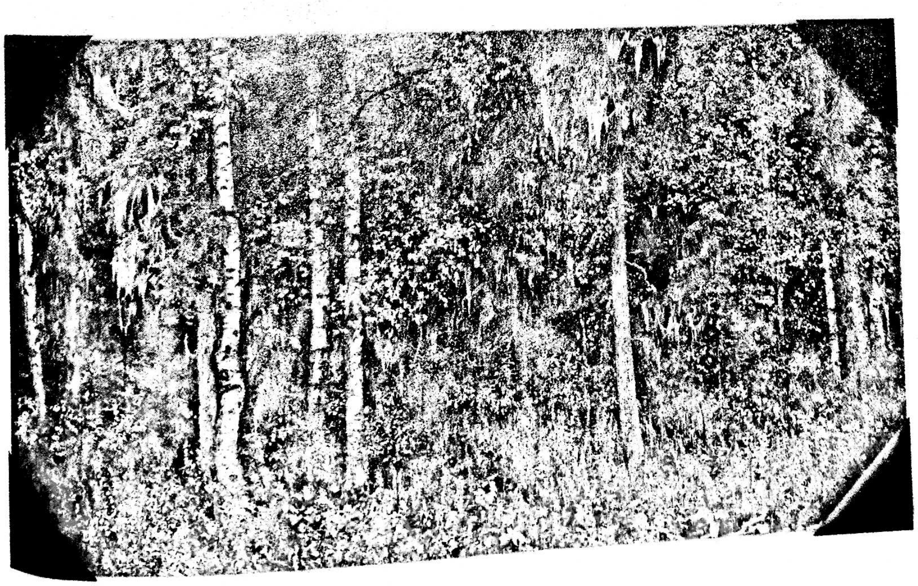
Mark-and-Recapture Studies Another estimating method is called "mark and recapture." Here's an example showing how mark and recapture works. First, turtles in a bay are caught in a way that does not harm them. Ecologists count the turtles and mark each turtle's shell with a dot of paint before releasing it. Two weeks later, the researchers return and capture turtles again. They count how many turtles have marks, showing that they have been recaptured, and how many are unmarked. Using a mathematical formula, the ecologists can estimate the total population of turtles in the bay. You can try this technique for yourself in the Skills Lab at the end of this section.

Reading Checkpoint **When might an ecologist use indirect observation to estimate a population?**

Lab zone Skills Activity

Calculating

An oyster bed is 100 meters long and 50 meters wide. In a 1-square-meter area you count 20 oysters. Estimate the population of oysters in the bed. (*Hint:* Drawing a diagram may help you set up your calculation.)



Sampling
To estimate the birch tree population in a forest, count the birches in a small area. Then multiply to find the number in the larger area.

Mark and Recapture
This researcher is releasing a marked turtle as part of a mark-and-recapture study.

Changes in Population Size

By returning to a location often and using one of the methods described on the previous pages, ecologists can monitor the size of a population over time. **Populations can change in size when new members join the population or when members leave the population.**

Births and Deaths The main way in which new individuals join a population is by being born into it. The **birth rate** of a population is the number of births in a population in a certain amount of time. For example, suppose that a population of 100 cottontail rabbits produces 600 young in a year. The birth rate in this population would be 600 young per year.

The main way that individuals leave a population is by dying. The **death rate** is the number of deaths in a population in a certain amount of time. If 400 rabbits die in a year in the population, the death rate would be 400 rabbits per year.

The Population Statement When the birth rate in a population is greater than the death rate, the population will generally increase. This can be written as a mathematical statement using the "is greater than" sign:

If birth rate > death rate, population size increases.

However, if the death rate in a population is greater than the birth rate, the population size will generally decrease. This can also be written as a mathematical statement:

If death rate > birth rate, population size decreases.

Immigration and Emigration The size of a population also can change when individuals move into or out of the population, just as the population of your town changes when families move into town or move away. **Immigration** (im ih GRAY shun) means moving into a population. **Emigration** (em ih GRAY shun) means leaving a population. For instance, if food is scarce, some members of an antelope herd may wander off in search of better grassland. If they become permanently separated from the population, they will no longer be part of that population.

Graphing Changes in Population Changes in a population's size can be displayed on a line graph. Figure 7 shows a graph of the changes in a rabbit population. The vertical axis shows the numbers of rabbits in the population, while the horizontal axis shows time. The graph shows the size of the population over a ten-year period.

Math Skills

Inequalities

The population statement is an example of an inequality. An inequality is a mathematical statement that compares two expressions. Two signs that represent inequalities are

< (is less than)

> (is greater than)

For example, an inequality comparing the fraction to the decimal 0.75 would be written

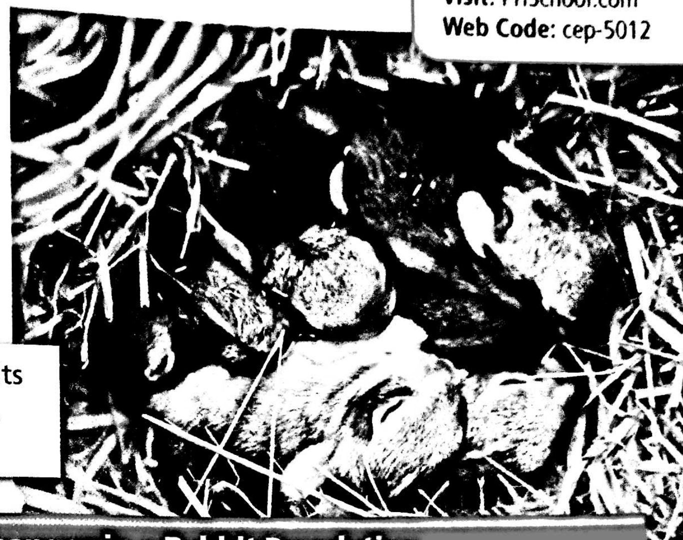
$$\frac{1}{2} < 0.75$$

Practice Problems Write an inequality comparing each pair of expressions below.

1. 5 ■ −6
2. 0.4 ■ $\frac{3}{5}$
3. −2 − (−8) ■ 7 − 1.5

FIGURE 7
This line graph shows how the size of a rabbit population changed over a ten-year period. **Interpreting Graphs** *In what year did the rabbit population reach its highest point? What was the size of the population in that year?*

▼ Young cottontail rabbits in a nest



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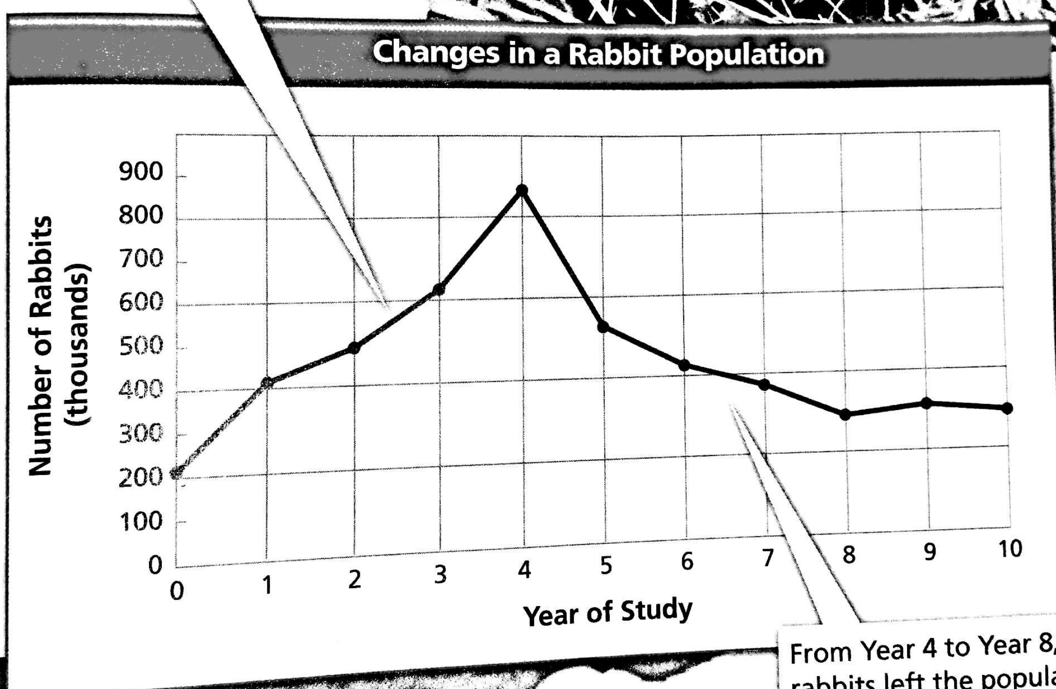
From Year 0 to Year 4, more rabbits joined the population than left it, so the population increased.



From Year 4 to Year 8, more rabbits left the population than joined it, so the population decreased.

◀ Cottontail rabbit caught by a fox

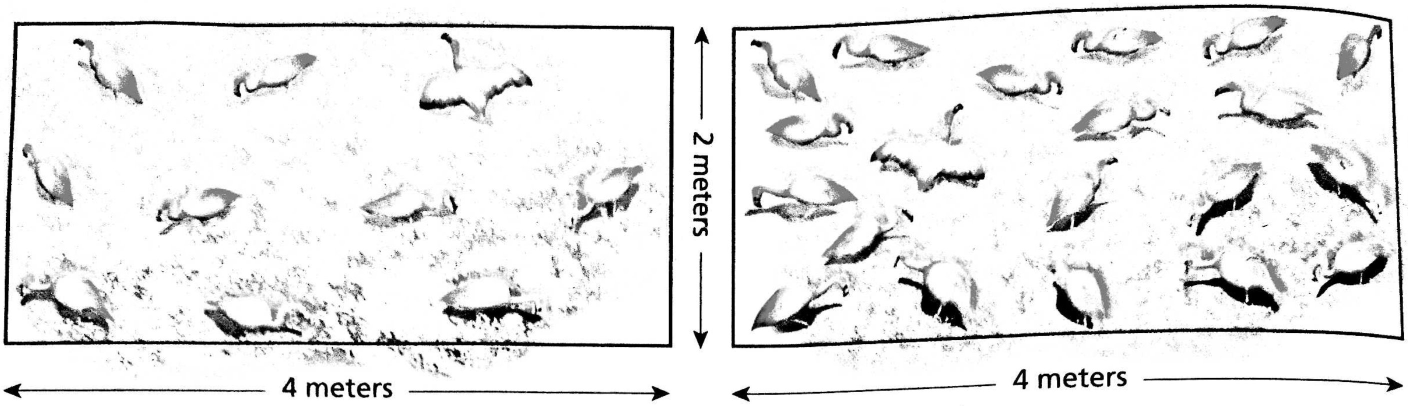
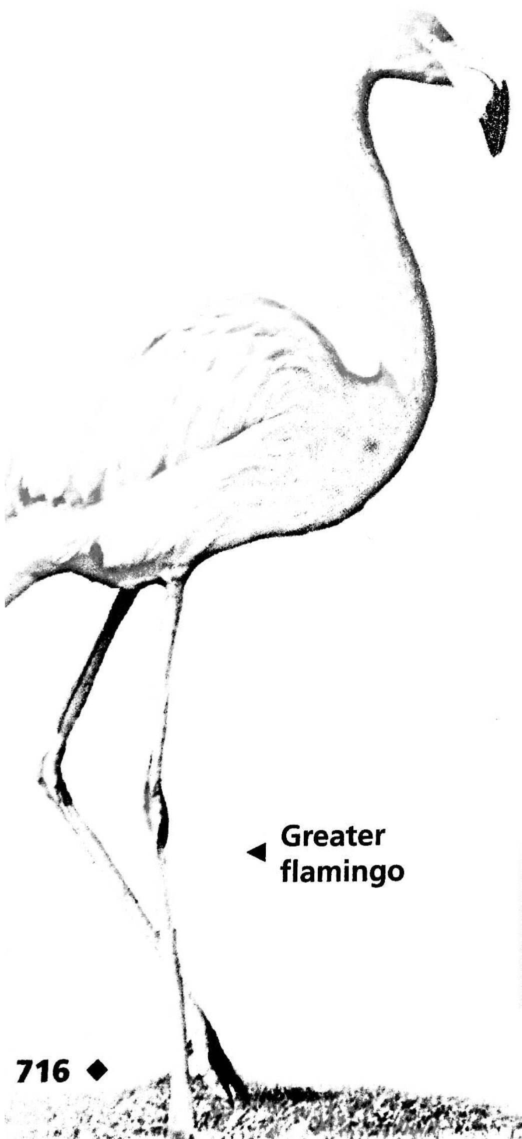


Figure 8
Population Density
In the pond on the top left, there are ten flamingos in 8 square meters. The population density is 1.25 flamingos per square meter. Calculating *What is the population density of the flamingos in the pond on the top right?*



◀ **Greater flamingo**

Population Density Sometimes an ecologist may need to know more than just the total size of a population. In many situations, it is helpful to know the **population density**—the number of individuals in an area of a specific size. Population density can be written as an equation:

$$\text{Population density} = \frac{\text{Number of individuals}}{\text{Unit area}}$$

For example, suppose you counted 20 monarch butterflies in a garden measuring 10 square meters. The population density would be 20 monarchs per 10 square meters, or 2 monarchs per square meter.

Reading Checkpoint **What is meant by the term *population density*?**

Limiting Factors

When the living conditions in an area are good, a population will generally grow. But eventually some environmental factor will cause the population to stop growing. A **limiting factor** is an environmental factor that causes a population to decrease. **Some limiting factors for populations are food and water, space, and weather conditions.**

Food and Water Organisms require food and water to survive. Since food and water are often in limited supply, they are often limiting factors. Suppose a giraffe must eat 10 kilograms of leaves each day to survive. The trees in an area can provide 100 kilograms of leaves a day while remaining healthy. Five giraffes could live easily in this area, since they would only require a total of 50 kilograms of food. But 15 giraffes could not all survive—there would not be enough food. No matter how much shelter, water, and other resources there were, the population would not grow much larger than 10 giraffes.

The largest population that an area can support is called its **carrying capacity.** The carrying capacity of this giraffe habitat would be 10 giraffes. A population usually stays near its carrying capacity because of the limiting factors in its habitat.

Space Space is another limiting factor for populations. Gannets are seabirds that are usually seen flying over the ocean. They come to land only to nest on rocky shores. But the nesting shores get very crowded. If a pair does not find room to nest, they will not be able to add any offspring to the gannet population. So nesting space on the shore is a limiting factor for gannets. If there were more nesting space, more gannets would be able to nest, and the population would increase.

Space is also a limiting factor for plants. The amount of space in which a plant grows determines whether the plant can obtain the sunlight, water, and soil nutrients it needs. For example, many pine seedlings sprout each year in a forest. But as the seedlings grow, the roots of those that are too close together run out of space. Branches from other trees may block the sunlight the seedlings need. Some of the seedlings then die, limiting the size of the pine population.

FIGURE 9
Food as a Limiting Factor
These jackals are fighting over the limited food available to them.

Lab zone **Try This Activity**

Elbow Room

1. Using masking tape, mark off several one-meter squares on the floor of your classroom.
2. Your teacher will set up groups of 2, 4, and 6 students. Each group's task is to put together a small jigsaw puzzle in one of the squares. All the group members must keep their feet within the square.
3. Time how long it takes your group to finish the puzzle.

Making Models How long did it take each group to complete the task? How does this activity show that space can be a limiting factor? What is the carrying capacity of puzzle-solvers in a square meter?

FIGURE 10
Space as a Limiting Factor
Could any more sunflower plants grow in this field? If not, the field has reached its carrying capacity for sunflowers.

FIGURE 11
Weather as a Limiting Factor A snowstorm can limit the size of an orange crop. **Applying Concepts** *What other weather conditions can limit population growth?*

Weather Weather conditions such as temperature and the amount of rainfall can also limit population growth. A cold snap in late spring can kill the young of many species of organisms, including birds and mammals. A hurricane or flood can wash away nests and burrows. Such unusual events can have long-lasting effects on population size.

Reading Checkpoint **What is one weather condition that can limit the growth of a population?**

Section 2 Assessment

Target Reading Skill Asking Questions Use the answers to the questions you wrote about the headings to help you answer the questions below.

Reviewing Key Concepts

1. a. **Listing** What are four methods of determining population size?
   b. **Applying Concepts** Which method would you use to determine the number of mushrooms growing on the floor of a large forest? Explain.
2. a. **Identifying** Name two ways organisms join a population and two ways organisms leave a population.
   b. **Calculating** Suppose a population of 100 mice has produced 600 young. If 200 mice have died, how many mice are in the population now? (Assume for this question that no mice have moved into or out of the population for other reasons.)
   c. **Drawing Conclusions** Suppose that you discovered that there were actually 750 mice in the population. How could you account for the difference?
3. a. **Reviewing** Name three limiting factors for populations.
   b. **Describing** Choose one of the limiting factors and describe how it limits population growth.
   c. **Inferring** How might the limiting factor you chose affect the pigeon population in your town?

Math Practice

4. **Inequalities** Complete the following inequality showing the relationship between carrying capacity and population size. Then explain why the inequality is true.

If population size ■ carrying capacity, then population size will decrease.