Activity 4

Factors Affecting Population Size

GOALS
In this activity you will:
• Investigate the factors that affect the size of a population.
• Interpret a graph and make calculations to examine factors affecting fluctuations in populations.
• Calculate the doubling time of the human population.
• Distinguish between an open and closed population.

What Do You Think?

The population of your community may be going up, going down, or remaining the same. The change depends on whether individuals are being added to or taken away from your community.

• What can take place in your community, or any other community of living things, that can influence the size of the population?

Write your answer to this question in your Active Biology log. Be prepared to discuss your ideas with your small group and other members of your class.

For You To Do

This activity provides an opportunity for you to examine the factors that affect the changes (fluctuations) that occur in a population in an ecosystem.
Part A: Reindeer Population

1. In 1911, 25 reindeer, 4 males and 21 females, were introduced onto St. Paul Island near Alaska. On St. Paul Island there were no predators of the reindeer, and no hunting of the reindeer was allowed. Study the graph shown below and answer the questions in your Active Biology log.

   a) In 1911 the population was 25 reindeer. What was the size of the population in 1920? What was the difference in the number of reindeer between 1911 and 1920? What was the average annual increase in the number of reindeer between 1911 and 1920?

   b) What was the difference in population size between the years 1920 and 1930? What was the average annual increase in the number of reindeer in the years between 1920 and 1930?

   c) What was the average annual increase in the number of reindeer in the years between 1930 and 1938?

   d) During which of the three periods 1911—1920, 1920—1930, or 1930—1938, was the increase in the population of reindeer greatest?

   e) What was the greatest number of reindeer found on St. Paul Island between 1910 and 1950? In what year did this occur?

   f) In 1950, only eight reindeer were still alive. What is the average annual decrease in the number of reindeer in the years between 1938 and 1950?

2. In your group, discuss the questions on the next page. Then answer them in your Active Biology log.
a) St. Paul Island is more than 323 km (200 miles) from the mainland. Could leaving or arriving at the island have played a major role in determining the size of the reindeer population? Explain your answer.

b) What might account for the tremendous increase in the population of reindeer between 1930 and 1938, as compared with the rate of growth during the first years the reindeer were on the island?

c) St. Paul Island is about 106 km² (41 square miles). What effect might 2000 reindeer have on the island and its vegetation?

d) Consider all the factors an organism requires to live. What might have happened on the island to cause the change in population size between 1938 and 1950?

e) Beginning in 1911, in which time spans did the reindeer population double? How many years did it take each of those doublings to occur? What happened to the doubling time between 1911 and 1938?

f) If some of the eight reindeer that were still alive in 1950 were males and some females, what do you predict would happen to the population in the next few years? Why?

g) What evidence is there that the carrying capacity (number of individuals in a population that the resources of a habitat can support) for reindeer on this island was exceeded?

h) What does this study tell you about unchecked population growth? What difference might hunters or predators have made?

Part B: Human Population

1. On a piece of graph paper, plot the growth of the human population using the following data.

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Coordinated Science for the 21st Century
2. Use your graph to determine the doubling times for the human population between A.D. 1 and 2000.

a) How much time elapsed before the human population of A.D. 1 doubled the first time?

b) Is the amount of time needed for the human population to double increasing or decreasing?

c) What does that indicate about how fast the human population is growing?

3. Extend your graph to the year 2010.

a) What do you estimate the human population will be in that year?

4. Using the equations below, estimate the doubling time for the current population based on the rate of growth from 1990 to 2000.

a) In what year will the present population double?

Annual rate of growth (in percent) = \frac{(\text{population in 2000} - \text{population in 1990}) \times 100}{\text{population in 1990} \times \text{number of years}}

\text{Doubling time} = \frac{70}{\text{annual rate of growth}}

d) What might happen to the population of humans if the present growth rate continues?

e) What methods could be used to reduce the growth rate?

f) Suggest several problems in the United States that are related to the human population.

g) What are the most important three or four factors to think about with regard to the world population?

5. In your group, discuss the following questions. Then answer them in your Active Biology log.

a) What similarities do you see between the graph of the reindeer population and your graph of the human population?

b) What are the three or four most important factors required to sustain a population?

c) In what ways is the Earth as a whole similar to an island such as St. Paul? Does the Earth have a carrying capacity? Explain your answer.

Activity 4 Factors Affecting Population Size

CHANGING POPULATION SIZES

Four Rates Determine Population Size

The size of a population changes through time. Suppose a biologist counted 700 ponderosa pines on a hill in Colorado in 1990. In 2000, when the biologist counted the trees again, there were only 500. In other words, there were 200 fewer trees in 2000 than in 1990.

This is a decrease in the population of ponderosa pines. This change in population may be expressed as a rate. To find the rate you divide the amount of change by the amount of time for the change to take place. The rate is an average. In this example, the rate of change in the number of trees divided by the change in time may be expressed as:

$$\frac{-200 \text{ trees}}{10 \text{ years}} = -20 \text{ trees per year}.$$ To the biologist, this means each year there were 20 fewer trees in the population. Keep in mind, however, that this rate is an average. It is unlikely the trees disappeared on a regular schedule. All of the trees may have been lost in one year due to a fire. Alternatively, selective cutting during several years may have caused the decrease.
What does the decrease of 200 pine trees in 10 years represent? Because pine trees cannot wander away, they must have died or have been cut down. In this situation, then, the decrease represents the death rate, or mortality rate, of the pine population. The number of deaths in the pine population per unit of time is the mortality rate. Mortality is not the only change that can affect a population, however. While some of the pines may have died, some young pine trees may have started to grow from seed. Death decreases a population; reproduction increases it. The rate at which reproduction increases the population is called the birthrate, or natality.

Organisms that can move have two other ways to bring about a change in population size. Suppose you were studying the pigeon population in your city or town. You might discover that a certain number of pigeons flew into the city in one year. This is called immigration. It occurs when one or more organisms move into an area where others of their type can be found. Immigration increases the population. While studying the pigeons, you might notice that a certain number flew out of the city. This is called emigration. It occurs when organisms leave the area. Emigration decreases the population. In any population that can move, then, natality and immigration increase the population. Mortality and emigration decrease the population. Thus, the size of any population is the result of the relationships among these rates.

Natality, mortality, immigration, and emigration rates apply to every population, including the human population. The sum of these rates makes up the growth rate of a population. The growth rate of a population is the number of organisms added to (or subtracted from) a population in a year due to natural increase and net migration. Often, this rate is expressed as a percentage of the population at the beginning of the time period.
Population Density May Fluctuate

Any population has a built-in, characteristic growth rate. This is the rate at which the group would grow if food and space were unlimited and individuals bred freely. Environmental factors do affect a population’s growth rate, however. The interaction of the population’s natural growth rate and the environment determines the density of the surviving population. The maximum number of individuals that a given environment can support is called the **carrying capacity**.

If you measure the density of a population at intervals during a given period of time, you seldom find any two consecutive measurements the same. Density increases or decreases continually. Most natural populations are **open populations**. These are populations in which individuals are free to emigrate or immigrate and in which the birth and death rates fluctuate. Variables in the environment, such as climate, available food, or the activities of natural enemies, are the causes of the fluctuations. In a closed population, birthrate and death rate are the only factors that affect the size of the population. The island of reindeer you studied in **Part A** is an example of a closed population.

**Bio Words**

- **carrying capacity**: the maximum population that can be sustained by a given supply of resources
- **open population**: a natural population in which all four factors that affect population size (death rate, birthrate, immigration, and emigration) are functioning
Sometimes population fluctuations are fairly regular, and the peaks are at approximately equal time intervals. For example, populations of lemmings often peak every three or four years. Many of the animals that live in the northern parts of Europe, Asia, and North America show similar population cycles. Although the data show very regular cycles when they are plotted on a graph, the reasons for the seemingly regular cycles are not well understood. A combination of purely chance events also can produce apparently regular cycles.

Although populations may change cyclically, many population changes are permanent. If a population becomes extinct, for example, the change is permanent. Any permanent change in a population is a change in the community to which the population belongs. Permanent changes in one population also may affect other populations of organisms in the same community.

Reflecting on the Activity and the Challenge

In this activity you discovered that birthrate, death rate, immigration, and emigration affect the growth rate of a natural, open population. Review the issue you have identified for research. Consider if any of the factors involving population size are relevant to the issue. You will be asked to explain to the public the importance of these factors in providing the science behind your stand.
Activity 4 Factors Affecting Population Size

**Biology to Go**

1. How do each of the four limiting factors affect population growth?
2. Explain how limiting factors could play a role in the extinction of a population.
3. Distinguish between an open and closed ecosystem. Use examples to illustrate your answer.
4. Scientists studying an area of the tundra reported that they found 5 lemmings per hectare. They returned the following year and discovered that the density of the lemmings in the same area were 20 per hectare. What is the rate of growth of lemmings in the area, expressed as a percentage?
5. According to the U.S. Census Bureau, the population of the United States is influenced by the following:
   - 1 birth every 8 s
   - 1 death every 13 s
   - 1 immigrant every 22 s.
   Use these figures to determine the time, in seconds, it takes for the net gain of one person. (Hint: Start by calculating the number of births, deaths, and immigrants every minute. Round off to whole numbers.)

**Inquiring Further**

1. Population growth in different parts of the world
   Research a place in the world where population growth is a problem today. How is it a problem? Research a place in the world where population growth is not a problem today. Why is it not a problem?
2. The truth behind lemming suicide
   During the filming of the 1958 Disney nature documentary *White Wilderness*, the film crew induced lemmings into jumping off a cliff and into the “sea” in order to document their supposedly suicidal behavior. Research and report on the truth of this statement and the truth about lemming “suicide.”