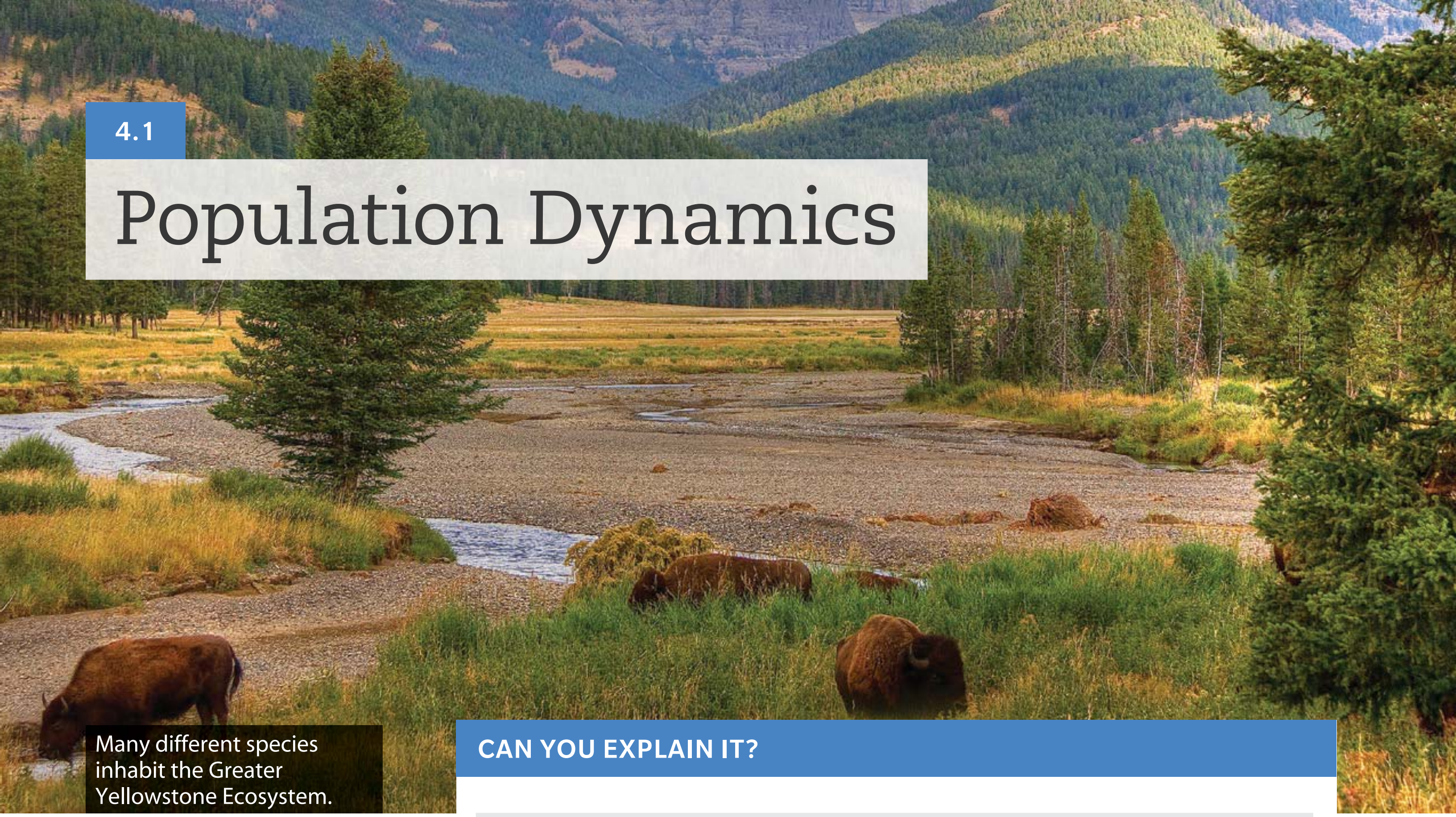


4.1

Population Dynamics

Many different species inhabit the Greater Yellowstone Ecosystem.

CAN YOU EXPLAIN IT?

FIGURE 1: About 500 wolves live in the Greater Yellowstone Ecosystem today. When first reintroduced to the ecosystem, there were only 31 wolves.

Gather Evidence As you explore the lesson, gather evidence for how populations interact in ecosystems.

Yellowstone National Park, located primarily in northwest Wyoming, is at the heart of the Greater Yellowstone Ecosystem. The rugged terrain and abundance of prey make this temperate ecosystem an ideal environment for wolves. However, due to aggressive eradication efforts in the 1800s and early 1900s, wolves were hunted to the point that they were no longer present in the park. By 1926, the last wolf pack in Yellowstone had been eliminated. The effect of such a change on an ecosystem was not well understood by scientists at that time.

In 1995, a program began to reintroduce wolves into Yellowstone National Park. During the first several years in which the wolf population was restored, observational studies reported that the diversity of plant species increased, certain songbirds returned, and aquatic ecosystems within the park changed.

Predict How might the reintroduction of wolves into Yellowstone National Park have caused both direct and indirect changes in populations of so many other species within their ecosystem?

Population Density and Dispersion

If you have ever traveled from a rural area to a city, you may have noticed a change in population density. Cities have more dense populations, while rural areas have more widely dispersed, or scattered, populations. Species populations are measured in a similar way. What can we learn from population data?

FIGURE 2: Cities have dense human populations.

Population Density

You may be familiar with the term *density* in the context of matter. It is the amount of matter in a given space. Population density is very similar: it is the number of individuals living in a defined space. When scientists such as wildlife biologists observe changes in population density over time, one of the things they study is whether the causes are due to environmental changes or natural variations in the life history of the species. The biologists use this information to decide whether it is necessary to make changes to maintain a healthy population.

One tool that biologists can use to make this decision is to calculate the ratio of individuals living in an area to the size of that area.

Collaborate With a partner, discuss whether the area where you live has a dense or dispersed population. Explain your reasoning.

Population density is calculated using the following formula:

$$\frac{\text{number of individuals}}{\text{area (units}^2\text{)}} = \text{population density}$$

To calculate this ratio for the deer herd shown in Figure 3, a biologist would first determine the size of the herd's territory. Then the scientist would count all of the individuals in that population within the defined area.

FIGURE 3: Deer gather in a field to graze.

Math Connection A scientist and her team counted 200 individual deer in an area of 10 square kilometers.

1. What is the population density?
2. Ten years later, scientists return to the same area and find that the population density has declined to 5 deer per square kilometer. What might a decrease in the density of a deer population tell scientists about the habitat in the area?

Population Dispersion

You may have noticed that people tend to separate themselves in different ways—some hang out in large groups, some gather in twos and threes, while others prefer to be alone. There are also patterns in the way different populations of other organisms separate themselves. Figure 4 shows three main patterns of population dispersal: clumped, uniform, and random.

Clumped dispersion occurs when resources are spread unevenly within an ecosystem. Individuals gather into groups where resources are available. Clumped dispersion helps protect individuals from predators and makes finding a mate easier. Uniform dispersion occurs when individuals of the same species must compete for limited resources and territory. Random dispersion is the least common pattern of distribution. It occurs when resources are evenly distributed within an ecosystem. In plants, this type of dispersion often occurs when seeds are scattered by wind or water, resulting in seeds being dropped randomly. The seeds will only sprout if conditions are right, which increases the randomness of the distribution.

Analyze Why might a population exhibit uniform dispersion? Think about why having a defined space might be beneficial.

FIGURE 4: Population Dispersion Patterns

a Clumped dispersion

b Uniform dispersion

c Random dispersion

Model Draw a diagram showing an overhead view of a population with each type of dispersion: clumped, uniform, and random.

Measuring Population Size

Measuring population size over a large area may seem like an impossible task. Sometimes, a complete count of every individual can be done, particularly if the species lives in an enclosed area. However, what if you needed to count a very large population over many square kilometers? In this case, biologists can use a variety of sampling techniques to estimate the size of a population.

One method scientists use to measure the size of a population of animals is the mark–recapture technique. Biologists capture individuals within a population, tag them, and then release them. After a period of time, a second sample is captured, and biologists look for and count the tagged individuals as well as any newly-captured animals. They may also fit animals with radio collars or GPS devices to track their movements. Another method is called quadrat sampling, in which ecologists use quadrats—typically square or rectangular grids of a known size—to collect data about population numbers in an ecosystem. Quadrat sampling works best with species that do not move, such as plants and corals.

Hands-On Lab

Quadrat Sampling

Use a quadrat sampling method to collect data about population numbers.

Predict Does quadrat sampling provide an accurate estimated of a population size within a defined area?

PROCEDURE

1. Obtain a quadrat frame. Measure, calculate, and record the area of the quadrat on a piece of paper or in your notebook.
2. Stand at the edge of the area you will sample and randomly throw your quadrat. Make sure your quadrat does not overlap with another.
3. Count how many individuals of each species are in your quadrat. Record your data in a data table. Repeat this procedure three times.

ANALYZE

1. Combine your data with that of your classmates. Find the average number of each species for all of the samples.
2. Obtain the area of the sampling plot from your teacher. Calculate how many quadrats would fit in the area of the sampling plot. Multiply this value by the average number of each species found in one quadrat to estimate the population of each species.

Scale, Proportion, and Quantity

1. Calculate the density of each species. Which species had the highest density? Which had the lowest? Why do you think that is? Compare your population estimates to the actual population number that your teacher provides. Was your estimate accurate? Why or why not?
2. How can you make sure that your estimate of population size will be as close to the actual population size as possible?
3. Why do scientists only gather data for a part of the population, instead of the entire population? How does this affect the accuracy of the final population count?

FIGURE 5: Quadrat sampling is most often used to survey populations of plants.

MATERIALS

- calculator
- meterstick
- quadrat

Explain In Yellowstone National Park, scientists track and gather data on many species to study population dynamics within the park, and to monitor the health of each population. Describe the types of data that scientists would need to gather to study the effects of reintroducing a population, such as wolves, on other populations in the park.

Population Growth Patterns

Predict What might happen to populations that cannot get enough resources?

Imagine you leave an apple in your locker over winter break. Upon your return to school, you open your locker door to find a cloud of fruit flies. When you left school, the fly population in your locker was zero—now it's at least 100! Your locker ecosystem had a huge change in its fruit fly population. This, hopefully, is not a normal occurrence in your locker, but changes in population sizes and densities in ecosystems are normal responses to changes in resource availability.

Population Size

FIGURE 6: A population of elephants has both young and old individuals.

How might biologists track the population size of a species, such as a group of elephants? To accurately track the population over time, they would need to account for four factors: immigration, emigration, births, and deaths.

Immigration and emigration have to do with individuals entering and leaving a population. For example, if a disturbance occurred in a nearby habitat, some elephants might immigrate, or move into, a new population. Then, competition could increase, causing some elephants to move out of the population, or emigrate, to a new area.

Births and deaths also change a population size over time. Individuals have offspring, which adds more members to the population. Some individuals die each year, which reduces the population.

Explain Which factors lead to an increase in a population, and which factors lead to a decrease in a population?

The growth rate of a population can be measured with an equation that takes into account these four factors:

$$r = (b + i) - (d + e)$$

In this equation, r = population growth rate, b = birth rate, i = immigration rate, d = death rate, and e = emigration rate. We can apply these factors to our locker ecosystem example. A small population of fruit flies immigrated into the locker in search of food. The population increased due to the birth of a new group of fruit flies. Those flies that did not die when you swatted them in surprise emigrated away from the locker when you threw the apple away.

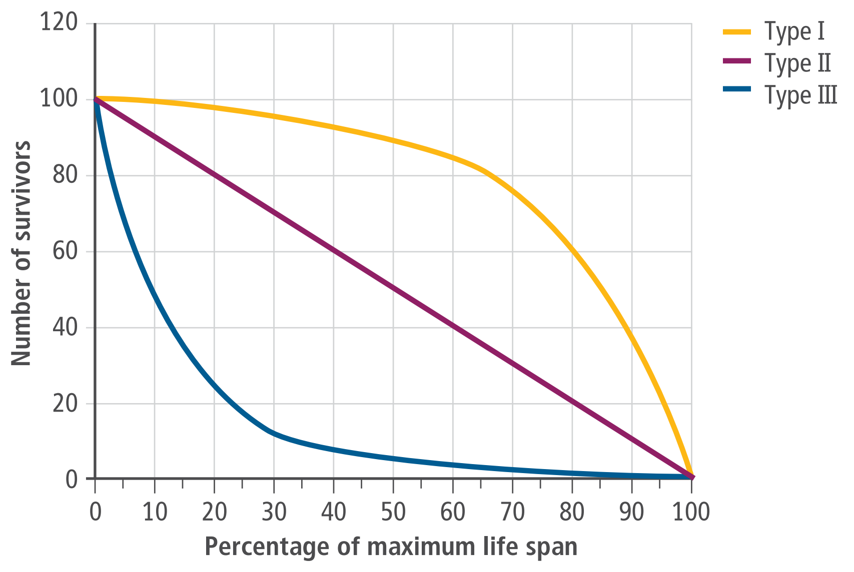
Problem Solving As part of a long-term elephant study, biologists counted individuals in a population of elephants each spring. In one year, there were 18 males and 34 females. Over the following year, each female gave birth, from which 28 offspring survived. Predators killed 9 elephants. A construction project cleared 50 acres of nearby forested land, causing 5 males and 19 females to immigrate into the study area. Competition for females increased, resulting in the emigration of 10 males to a new territory in search of mates. Calculate the growth rate of this population.

Survivorship Curves

Biologists are also interested in the reproductive strategy of a population. Reproductive strategies include behaviors that can improve the chances of producing offspring or behaviors that can increase the survivorship rate of offspring after birth. Parental care is an example of a reproductive strategy. Parental care is especially important for species that produce offspring that cannot take care of themselves. By protecting their young, parents are better able to make sure their young stay alive until they can survive on their own. A population's reproductive strategies can be assessed using a survivorship curve. Figure 7 shows the three types of survivorship curves.

Survivorship Curves

FIGURE 7: There are three main types of survivorship curves.



A survivorship curve is a simplified diagram that shows the number of surviving individuals over time from a measured set of births. By measuring the number of offspring born in a year and following those offspring through until death, survivorship curves give information about the life history of a species.

Collaborate With a partner, discuss which type of survivorship humans exhibit.

Some species have a small number of offspring, and many of the offspring live long enough to reach old age. Mammals and other large animals generally exhibit this Type 1 survivorship curve. Other species have a large number of offspring, but many of these offspring do not survive long enough to reproduce. Many invertebrates, fish, and plants exhibit this Type III survivorship. A fish may lay hundreds or thousands of eggs, but only a small percentage of its offspring will survive to adulthood.

Between these two extremes is a third type of survivorship, in which the survivorship rate is roughly equal at all stages of an organism's life. At all times, these species have an equal chance of dying, whether from disease or as a result of predation. Organisms such as birds, small mammals, and some reptiles exhibit this Type II survivorship.

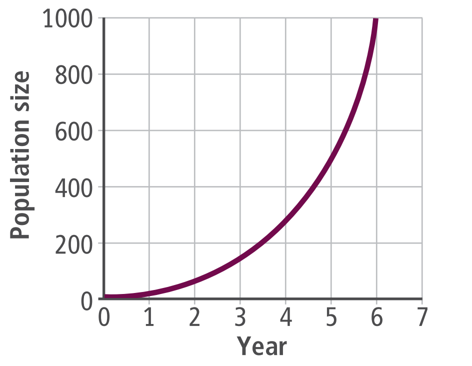
Analyze Can a survivorship curve be used to determine whether or not a species cares for their young? Explain your answer.

Exponential and Logistic Growth

Population growth depends on the environment and available resources. The rate of growth for a population is directly determined by the amount of available resources. A population may grow very rapidly, or it may grow slowly over time.

Analyze According to the graph in Figure 8, during which time period is population growth occurring at the fastest rate?

FIGURE 8: Exponential Growth



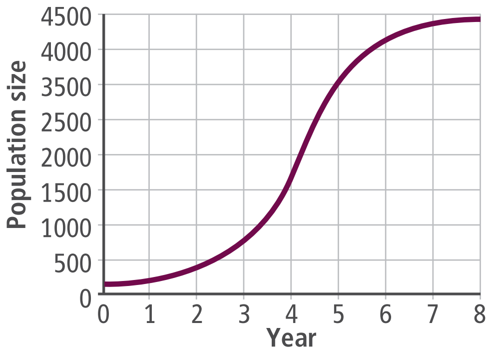
Exponential Growth

Almost any species that lives in ideal conditions of available resources, space, and other factors will rapidly increase in population. This type of growth, called exponential growth, occurs when a population size increases dramatically over a relatively short amount of time. As shown in Figure 8, a graph of exponential growth looks like a J-shaped curve.

Exponential growth may occur when a species moves into a previously uninhabited area. A real-world example of exponential growth in a population occurred in 1859, when an Australian landowner brought 24 rabbits into the country for sport hunting and released them into the wild. With no predators, abundant space, and plentiful resources, the rabbit population grew exponentially and spread across the country. After many unsuccessful attempts to control the population, Australian officials estimate today's population to be between 100 and 200 million rabbits.

Analyze According to the graph in Figure 9, when would you expect competition among individuals to be the least?

FIGURE 9: Logistic Growth



Logistic Growth

When a population is growing exponentially, resources are plentiful and there are no factors to interfere with survivability. However, most populations face limited resources and thus show a logistic growth pattern. During logistic growth, a population begins with a period of slow growth followed by a period of exponential growth before leveling off at a stable size. A graph of logistic growth takes the form of an S-shaped curve, as shown in Figure 9. During the initial growth period, resources are abundant, and the population is able to grow at a quick rate. Over time, resources are reduced, and growth starts to slow. As resources become even more limited, the population levels off at a size the environment can support.

Explain When wolves were reintroduced into Yellowstone National Park, the populations of many other species began to change.

1. Which factors would scientists want to measure in order to learn how each population changed over time?
2. How would scientists know if populations were increasing or decreasing over time?
3. How might the introduction of wolves change the growth patterns of other species?

Factors That Limit Population Growth

Because natural conditions are neither ideal nor constant, populations cannot grow forever. Instead, resources are used up or an ecosystem changes, causing deaths to increase or births to decrease within a population.

Carrying Capacity

The carrying capacity of an environment is the maximum population size of a species that a particular environment can normally and consistently support in terms of resources. As shown in Figure 10, once a population hits this limit, certain factors then keep it from continued growth. These factors include availability of resources such as food, water, and space, as well as competition among individuals.

The carrying capacity of an environment can change at any given time. For example, sudden and rapid flooding could reduce the availability of food or shelter in an ecosystem. This change would lower the environment's carrying capacity. As a result, fewer individuals would be supported by the environment. When conditions improve, however, the carrying capacity would increase, and the environment would again be able to support a larger population of that particular species.

Explore Online

Hands-On Activity

Modeling Carrying Capacity
Model predation and the effects of environmental changes on a population and the environment's carrying capacity.

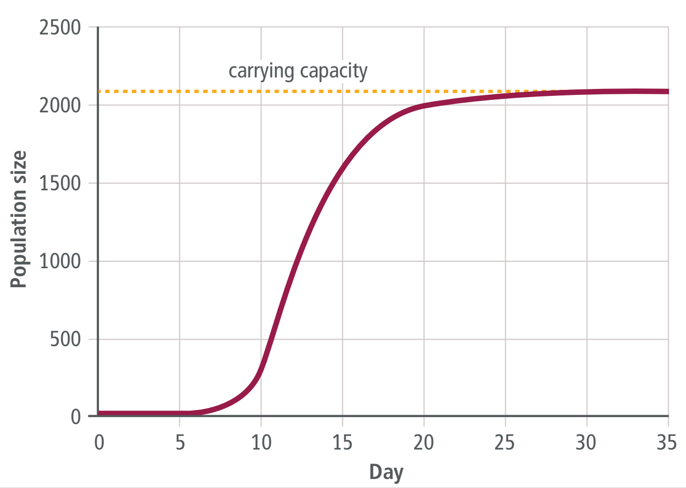


FIGURE 10: An environment's carrying capacity limits the growth of a population.

Predict How might this graph change if an ecosystem experienced drought conditions?

Limiting Factors

Many factors can affect the carrying capacity of an environment for a population of organisms. A factor that has the greatest effect in keeping down the size of a population is called a limiting factor. There are two categories of limiting factors—density-dependent and density-independent.

Density–Dependent Limiting Factors

Density–dependent factors are factors that are affected by the number of individuals in an area. The larger the population, the greater the effect. Density–dependent limiting factors include the following:

Competition Both plants and animals compete among themselves for needed resources. As a population becomes more dense, the resources are used up, limiting how large the population can grow.

Predation The relationship between predator and prey in an environment is ongoing and constantly changing. Predator populations can be limited by the number of available prey, and the prey population can be limited by being caught for food.

Parasitism and disease Parasites are much like predators as they live off their hosts, weakening them, and even sometimes killing them. Parasites and disease spread more quickly through dense populations. The more crowded an area becomes, the easier it is for parasites and disease to spread.

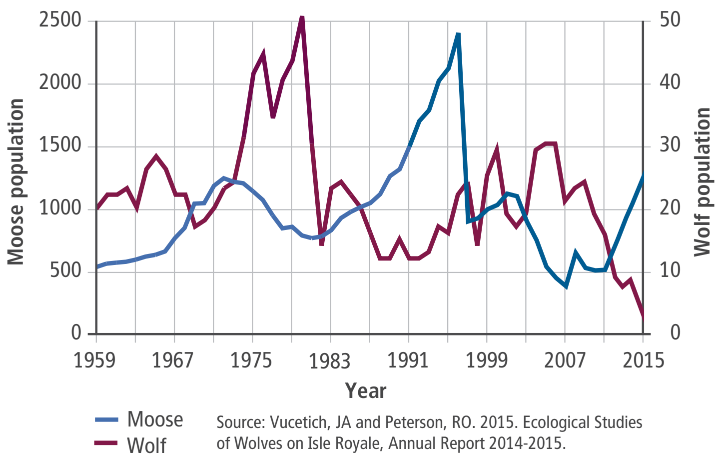
Data Analysis

Moose–Wolf Interactions on Isle Royale

For over 50 years, the wolf and moose populations on Isle Royale in Lake Superior served as a classic example of how predator-prey interactions limit population growth. As shown in Figure 11, changes in population size occur in an offset manner. In other words, it takes some time for an increase or decrease in one population to affect the other. Over time, the populations rise and fall in a pattern.

Density-Dependent Limiting Factors

FIGURE 11: Predator–Prey Interactions on Isle Royale



Analyze Study the graph showing the moose–wolf interactions on Isle Royale.

1. Based on this graph, what is the most likely explanation for the increase in the moose population between 1989 and 1995?
2. In 2016, the wolf population on Isle Royale declined to only two individuals. How will the lack of wolves affect the moose population? Will the moose population grow exponentially? Explain your answers.

Density–Independent Limiting Factors

Density–independent factors are factors that can impact a population regardless of its density. These factors include things such as:

Weather Any weather-related event such as a drought, flood, frost, or severe storm can wipe out a population or destroy their sources of food, water, or shelter.

Natural disasters Volcanic eruptions, earthquakes, tsunamis, and fires usually result in a sudden decrease in population size.

Human activity Habitats, and sometimes entire ecosystems, are degraded or even completely destroyed by human activities such as forest clearing, draining of wetlands for land development, and habitat fragmentation by roads and fences.

FIGURE 12: Forest fires kill plants and animals and force animal populations to flee.

Explore Online

Limiting Factors Go online to view an animation of limiting factors in an ecosystem.

Explain Why is fire considered a density–independent limiting factor?

Human activities have had a significant effect on populations. For example, the introduction of nonnative species has caused population crashes in many parts of the world where biodiversity is an important part of ecosystem stability. Nonnative species are species that are brought into ecosystems in which they do not normally live. In some cases, the nonnative species may outcompete one or more native species for resources. Because of the complex network of ecosystems, such effects could alter the ecosystem food web. In some extreme cases, the extinction of a species may occur.

Gather Evidence When wolves were reintroduced into Yellowstone National Park, scientists noticed that the populations of elk and coyotes decreased. They also noticed that populations of beaver and willow trees increased. Describe the factors that might have led to these changes in the different populations, and explain how these factors would affect the carrying capacity of the environment for each species.

Careers in Science

Biogeographer

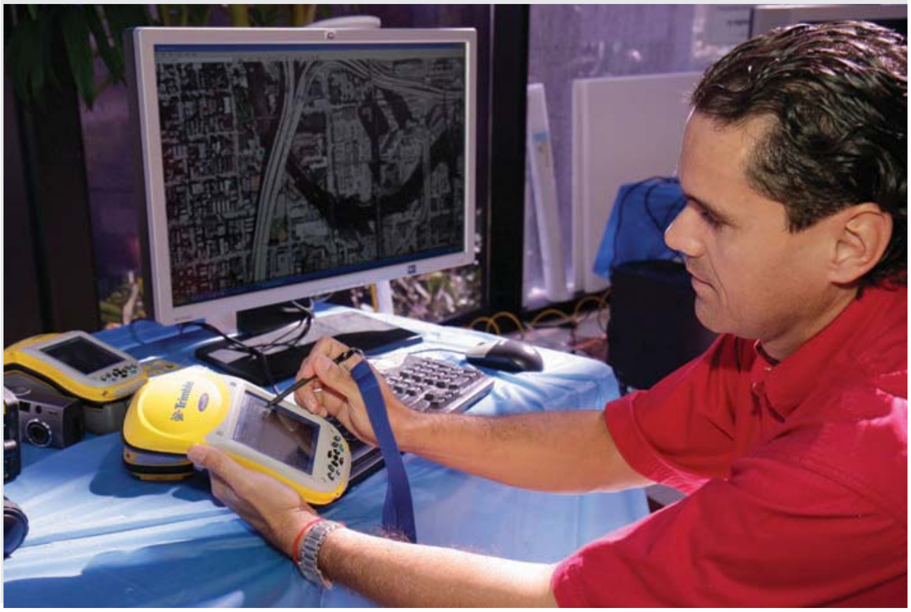
Biogeographers are often involved with the protection, conservation, and management of natural resources. Where plant and animal species live, how they got there, and how future conditions might affect their populations are just a few of the topics that biogeographers study.

Technology is an important part of a biogeographer's toolset. They use a digital tool called geographic information systems, or GIS, to make data-rich maps. GIS can use any data that is related to location such as population size, land type, and the location of human infrastructure such as roadways, power lines, and building locations. Biogeographers use GIS along with statistical models to map and study populations, habitats, ecosystems, and ecological processes.

A variety of job titles and work settings are connected with this career. Someone with a degree in biogeography might work as a city or county planner, as a mapping technician, or as a GIS specialist. Biogeographers work for city, state, or federal government agencies, for nonprofit and private organizations, or they might work in an academic setting as university professors or researchers.

Biogeography uses knowledge from a wide range of subjects. Along with general geography and cartography, or map making courses, students may also take classes in economics, computer science, history, mathematics, ecology, and evolutionary biology.

FIGURE 13: Biogeographers use digital tools such as geographic information systems (GIS) to study the distribution of plant and animal species.



Biogeographers often discuss the results of their research in written technical reports or in presentations given within their agency or to the public. Therefore, a career in biogeography also requires excellent writing and communication skills, so a strong background in language arts is particularly useful.

As our knowledge of climate change continues to grow, biogeographers will play an important role in determining how environmental changes will impact the global geographical distribution of populations of different species. The information gathered by biogeographers could be used to come up with solutions to help solve these problems and to prevent species from going extinct.

Language Arts Connection
A state wildlife management agency is considering reintroducing bobcats back into a forested area where they once flourished. Imagine you are the agency's biogeographer. Using your knowledge of population dynamics and carrying capacity, what questions would you ask and investigate to determine whether or not the area they have selected is appropriate for this reintroduction? What kind of data would you need to collect? Develop and record a plan for investigation and determine what questions you would need answered before the reintroduction could proceed.

POPULATION DENSITY AND CARRYING CAPACITY

CONTROLLING THE EXPONENTIAL GROWTH OF NONNATIVE SPECIES

Go online to choose one of these other paths.

Lesson Self-Check

CAN YOU EXPLAIN IT?

FIGURE 14: Wolf reintroduction in Yellowstone National Park had a complex impact on the ecosystem as a whole.

Wolf removal was one of many factors that changed the ecology of Yellowstone National Park from 1926 until the early 1990s. Eliminating a predator helped the elk population rise. Elk and beaver competed for some of the same food resources, including willow trees. As willow trees were reduced by larger elk herds, fewer beavers were able to survive in the park. Fewer beaver dams meant fewer marshy environments, which are ideal willow habitat.

Explain Refer to the notes in your Evidence Notebook to explain how the reintroduction of wolves into the Greater Yellowstone Ecosystem might have caused both direct and indirect changes in the populations of so many other species within their ecosystem. Write a short explanatory text that cites specific evidence from this lesson about population dynamics to support your answer.

Interactions within any ecosystem, whether it be large or small, are often very complex. All species within an ecosystem are connected. The impact and causes of change in a system can be difficult to determine. The removal and later reintroduction of wolves in Yellowstone definitely had the potential to cause change. But recent research has called into question how significant their impact really was. While at first there was evidence that aspen and willow growth was occurring immediately after the wolves were reintroduced, long-term studies indicate that this wasn't actually the case.

Research by scientists at Colorado State University that focused on Yellowstone's willows found that the complete removal of wolves from the ecosystem had actually caused permanent changes to the region. When the wolves were removed from the system, elks removed nearly all of the region's willow trees. Without willows to eat, the beaver population decreased. No beavers meant no beaver dams, which caused the once slow-moving waters to now cut deeply into the terrain. As a result, the water table dropped far below the level where willows can survive. Even if the elk population were drastically reduced by the newly reintroduced wolves, willow populations would not recover.

CHECKPOINTS

Check Your Understanding

1. Which of these abiotic factors would contribute to a clumped dispersion pattern in an ecosystem? Select all correct answers.
   a. unlimited water
   b. limited water
   c. high temperatures
   d. limited sunlight

2. A population of antelope has a negative population growth rate. Which of these conditions must also be true for the population growth rate to be negative?
   a. births + deaths < immigrations + emigrations
   b. births + deaths > immigrations + emigrations
   c. births + immigrations < deaths + emigrations
   d. births + immigrations > deaths + emigrations

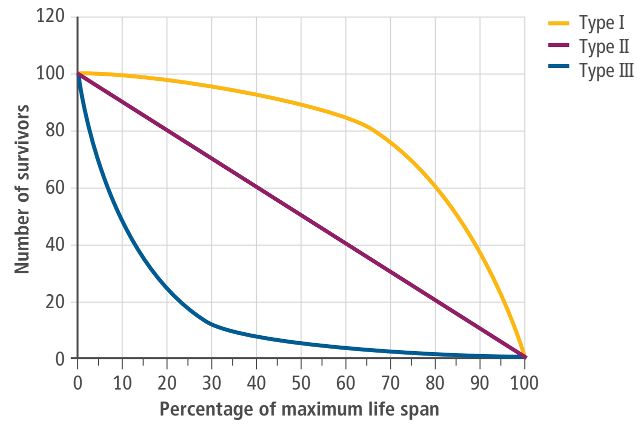
3. A population of warblers, a type of songbird, experiences a period of exponential growth. Which of these factors would be a density–dependent limiting factor that could decrease the carrying capacity of the ecosystem for this population of songbirds?
   a. a competing species moves into the forest
   b. a period of lower than normal rainfall
   c. a builder removes trees for an office park
   d. high winds knock down a quarter of the trees

4. A population of deer is displaced by a massive flood in their habitat following a severe rainstorm. The flood is an example of
   a. a density–dependent limiting factor.
   b. carrying capacity.
   c. a density–independent limiting factor.
   d. survivorship.

5. A population of rodents is introduced on a remote island due to a shipwreck. Eventually, the population reaches the island's carrying capacity. At this point, the birth and death rates are
   a. relatively equal.
   b. crashing.
   c. density independent.
   d. density dependent.

Use the graph to answer questions 6–9.

FIGURE 15: Survivorship Curves



6. A female salamander lays hundreds of eggs at a time. However, after hatching, few of the larvae survive to adulthood. According to the graph, which type of survivorship does the salamander exhibit?
   a. Type I
   b. Type II
   c. Type III

7. A songbird has an equal chance of surviving at all stages of its life. According to the graph, which type of survivorship does the songbird exhibit?
   a. Type I
   b. Type II
   c. Type III

8. Which survivorship type is associated with parental care?

9. What is the connection between survivorship curves and reproductive strategies?

10. A herd of zebras has 9 males and 62 females. During a one-year period, 22 foals that are born survive and 25 adults die. Six females join the herd. Three males and 11 females leave the herd. Has the ecosystem reached carrying capacity for the herd? How do you know?

11. Draw a graph of logistic growth. Label the point at which the resources for the population are no longer abundant enough to support exponential growth. Explain your reasoning.

12. A sourdough bread starter is a colony of yeast that bakers keep alive, sometimes for years. The bread is made by removing a portion of the colony, which is replaced by adding back an equal volume of a solution of water, sugar, and flour. Is the starter a model for exponential growth or logistic growth? Explain your reasoning.

13. Describe three advantages an individual organism might have by living in a population with a clumped dispersal pattern.

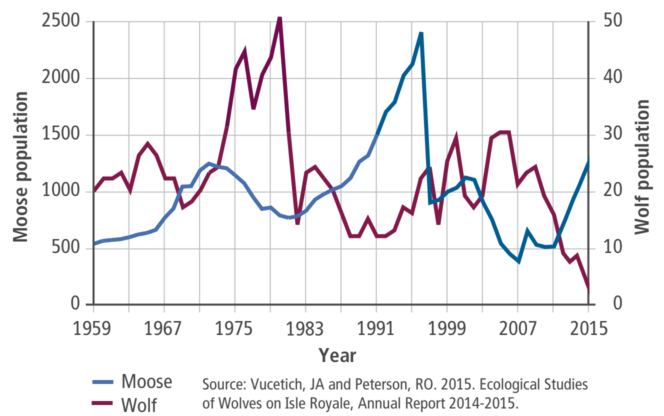
14. A population of algae that lives in a pond is limited in size by the amount of sunlight that strikes the pond's surface. Is sunlight a density-dependent or density-independent limiting factor for the algae population? Explain your answer.

15. What might cause exponential growth to occur only for a short period when a new species is introduced to a resource-filled environment?

Use the graph to answer Questions 16–18.

Density-Dependent Limiting Factors

FIGURE 16: Predator–Prey Interactions on Isle Royale



16. How does the wolf population on Isle Royale affect the carrying capacity of the moose population?

17. Is there evidence from the data to suggest that the wolf population crashed? What might have caused this population crash?

18. Is there evidence from the data to suggest that the moose population crashed? What might have led to this population crash?

MAKE YOUR OWN STUDY GUIDE

In your Evidence Notebook, design a study guide that supports the main idea from this lesson:

Populations grow in predictable patterns and are limited by resource availability.

Remember to include the following information in your study guide:

- Use examples that model main ideas.
- Record explanations for the phenomena you investigated.
- Use evidence to support your explanations. Your support can include drawings, data, graphs, laboratory conclusions, and other evidence recorded throughout the lesson.

Consider how ecological factors such as resource availability limit population growth.