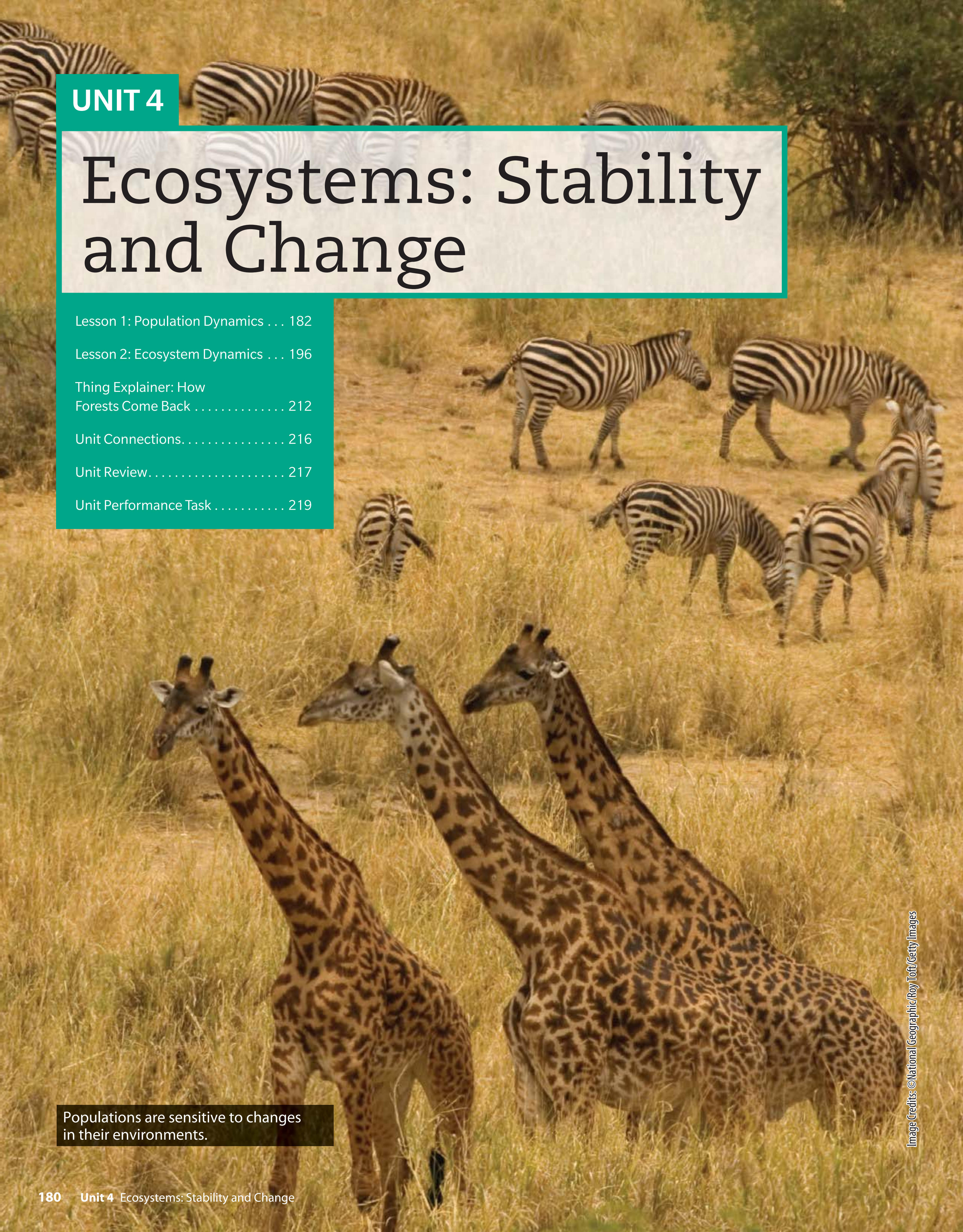


UNIT 4

Ecosystems: Stability and Change

Populations are sensitive to changes in their environments.

FIGURE 1: Pigeon populations can grow out of control.

Pigeons were domesticated and bred by people thousands of years ago. Pigeons were often used as message carriers because of their ability to find their way home even over long distances. Today, however, the pigeon population has boomed and the birds are damaging buildings, statues, and landmarks. Cities often use wire and netting to keep the birds out and off of buildings. These devices cause the birds to move to a new location but don't reduce the population. Some cities are looking into different forms of birth control to reduce the population to more manageable numbers.

Predict How do you think changes in population size can affect the composition and stability of an ecosystem?

DRIVING QUESTIONS

As you move through the unit, gather evidence to help you answer the following questions. In your Evidence Notebook, record what you already know about these topics and any questions you have about them.

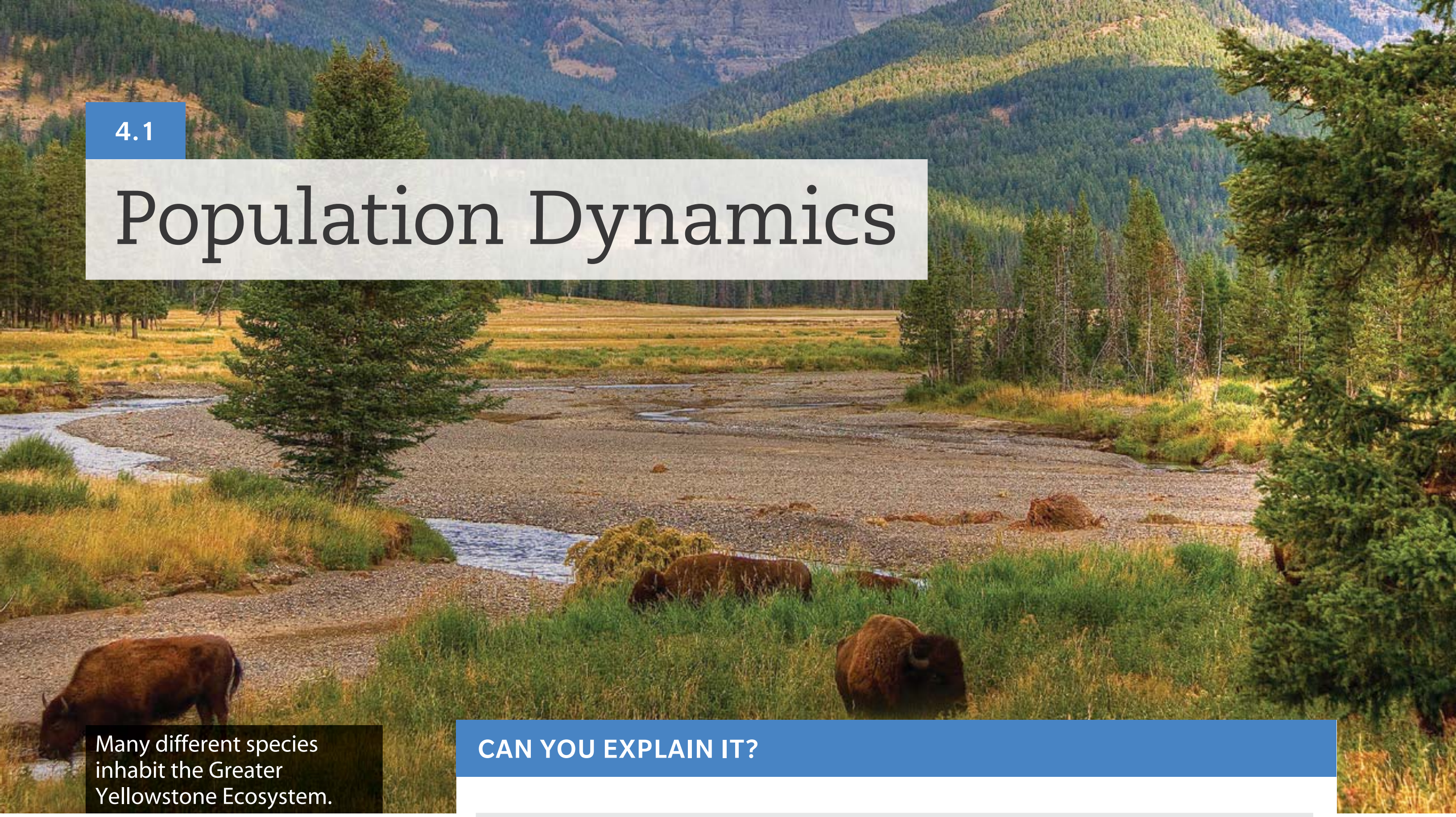
1. How do scientists measure population and changes in population?
2. What causes populations and ecosystems to remain stable or to change over time?
3. What factors affect populations within an ecosystem?
4. How do modest or drastic changes in ecosystems affect ecosystem stability?

UNIT PROJECT

Wetlands at Your Service

Wetlands are ecosystems that have water at or near the soil surface at various times of the year. Examples of wetlands include marshes and swamps. Wetlands often form along the boundaries of water features, such as lakes or rivers. How do wetlands help stabilize ecosystems and populations? Model your own wetland and investigate the services wetlands provide for humans and the ecosystem. How might the destruction of wetlands change the composition of populations and ecosystems?

Go online to download the Unit Project Worksheet to help plan your project.



4.1

Population Dynamics

Many different species inhabit the Greater Yellowstone Ecosystem.

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

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.

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?

Image Credits: (t) ©Michael H Spivak/Moment/Getty Images; (b) ©SBTheGreenMan/iStock/Getty Images Plus

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?

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

MATERIALS

- calculator
- meterstick
- quadrat

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?

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.

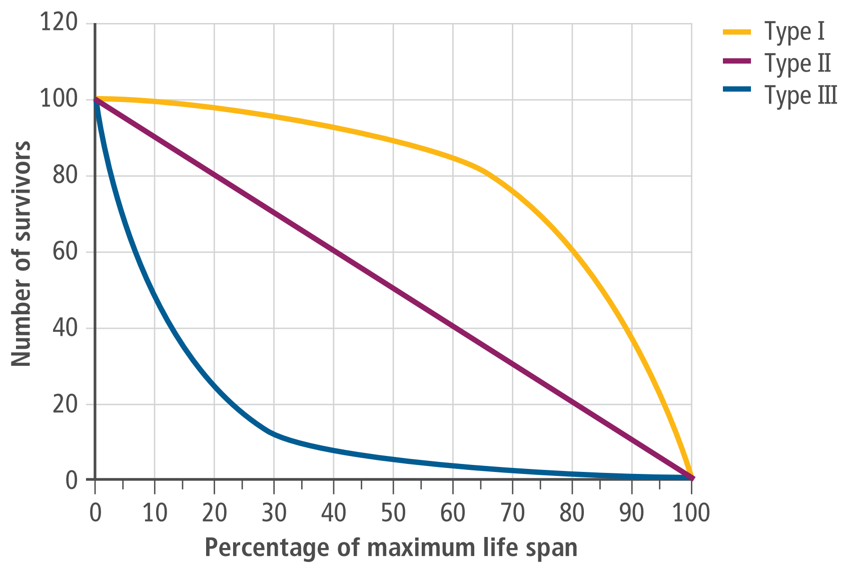
Problem Solving As part of a long-term elephant study, biologists counted individuals in a population of elephants each spring. In one year, there were 18 males and 34 females. Over the following year, each female gave birth, from which 28 offspring survived. Predators killed 9 elephants. A construction 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.

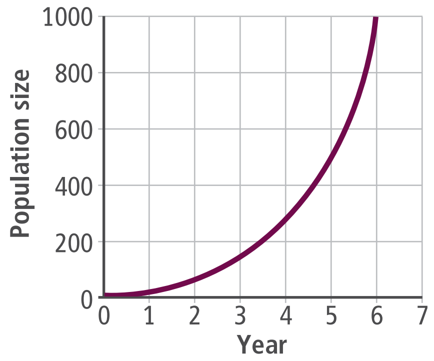
Analyze Can a survivorship curve be used to determine whether or not a species cares for their young? Explain your answer.

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



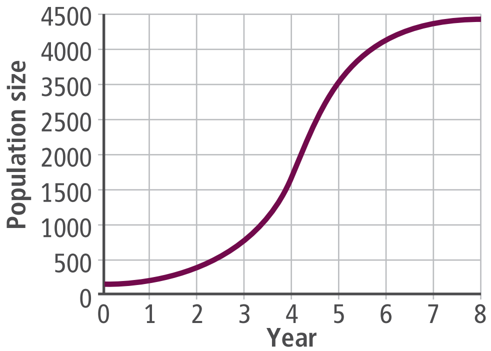
Exponential Growth

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.

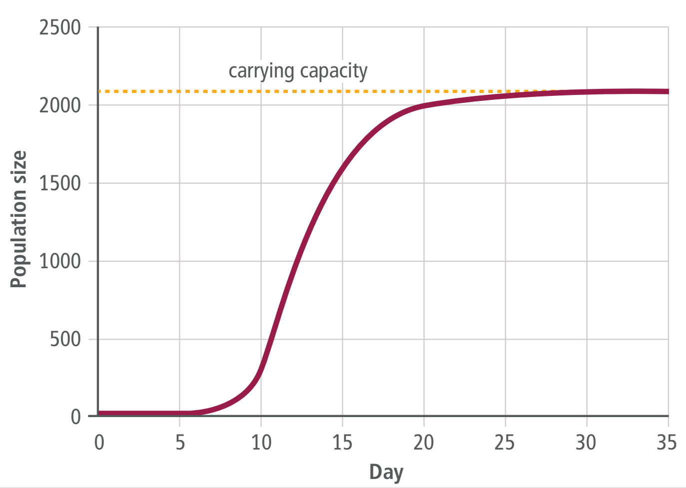


FIGURE 10: An environment's carrying capacity limits the growth of a population.

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.

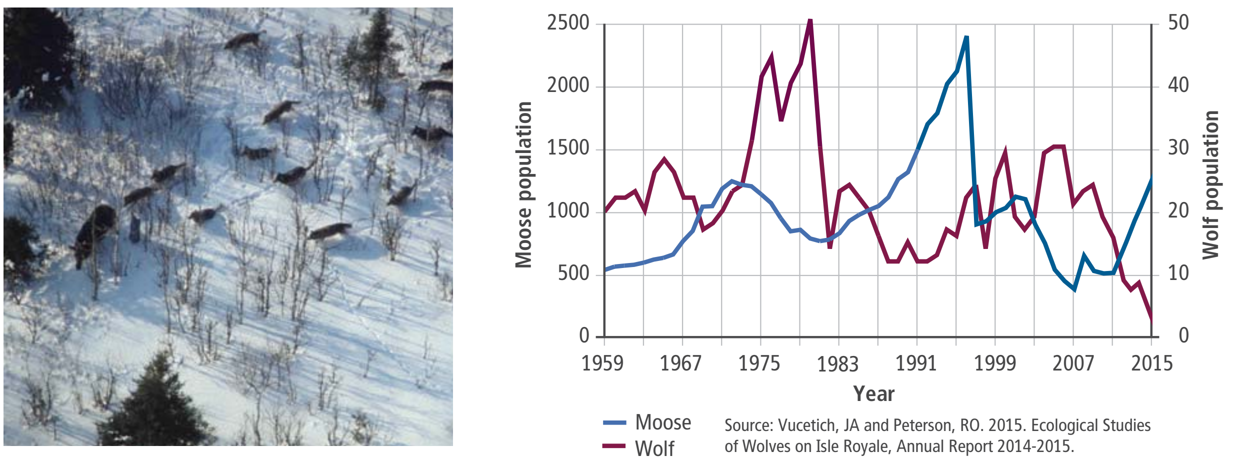
Data Analysis

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

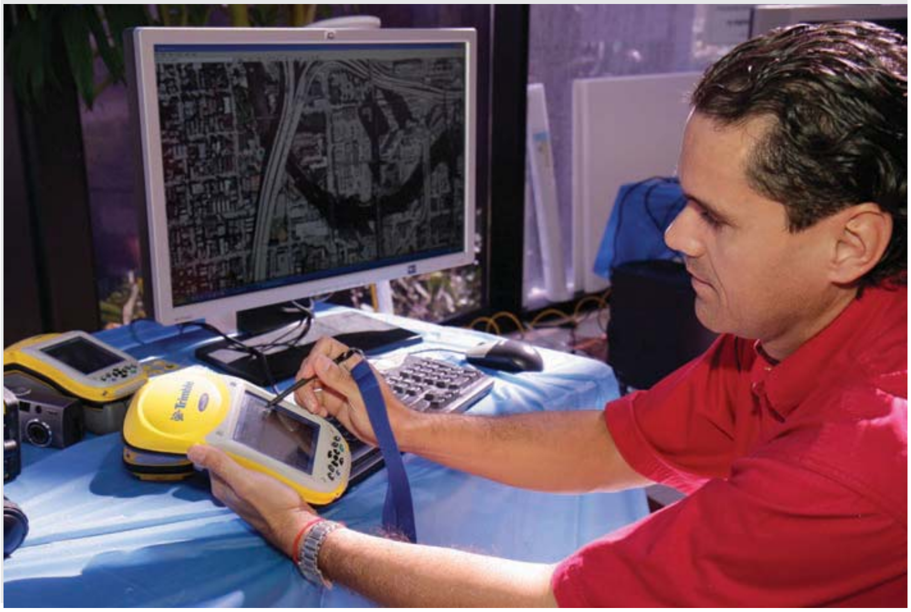
Biogeographers are often involved with the protection, conservation, and management of natural resources. Where plant and animal species live, how they got there, and how future conditions might affect their populations are just a few of the topics that biogeographers study.

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

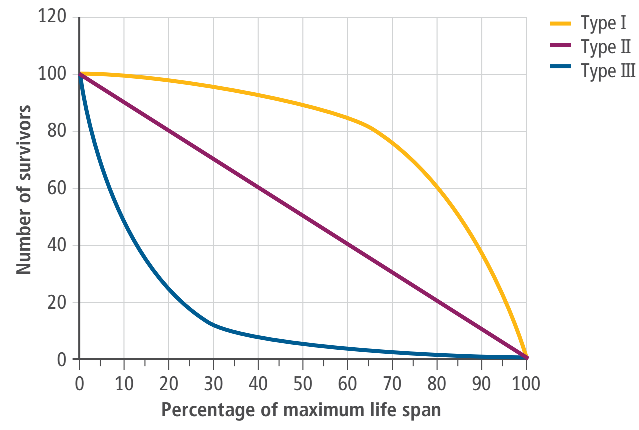
3. A population of warblers, a type of songbird, experiences a period of exponential growth. Which of these factors would be a density–dependent limiting factor that could decrease the carrying capacity of the ecosystem for this population of songbirds?
   a. a competing species moves into the forest
   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.

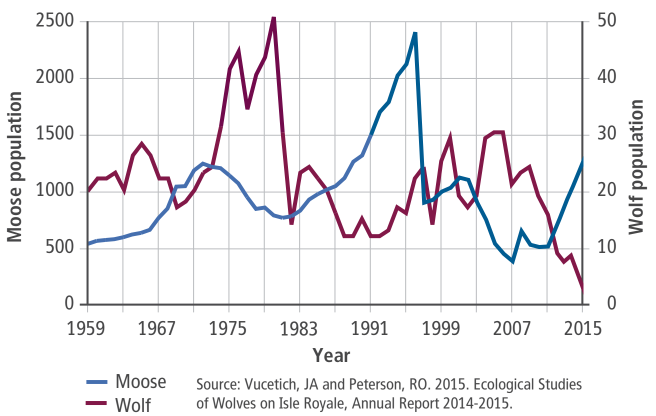
14. A population of algae that lives in a pond is limited in size by the amount of sunlight that strikes the pond's surface. Is sunlight a density-dependent or density-independent limiting factor for the algae population? Explain your answer.

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



Source: Vucetich, JA and Peterson, RO. 2015. Ecological Studies of Wolves on Isle Royale, Annual Report 2014-2015.

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.

4.2

Ecosystem Dynamics

Lava flow from a volcanic eruption can change an ecosystem dramatically.

CAN YOU EXPLAIN IT?

Gather Evidence As you explore the lesson, gather evidence for how ecosystems maintain stability over time.

FIGURE 1: A young plant grows in a crack in a sheet of bare volcanic rock.

Molten lava flowing from a volcano burns everything in its path. When it cools, a layer of solid rock is left behind. However, over time, a new ecosystem will become established on this seemingly lifeless landscape.

Predict How do you think an ecosystem can be reestablished in an area after a disturbance such as a volcano?

Interactions in Ecosystems

The ways in which flamingos interact with other organisms and their environment are only a small part of the ecology of a tropical lagoon ecosystem. To understand what individuals, populations, and communities need to survive, ecologists study the interactions among and between species and their environment.

FIGURE 2: Flamingos live and feed in large groups.

Habitat and Niche

Flamingos live in tropical and subtropical regions of the world. They prefer environments that have alkaline lakes or saltwater lagoons and large mud flats. These environmental features are examples of a flamingo's habitat. A habitat includes all of the biotic and abiotic factors in the environment where an organism lives. For a flamingo, these factors include things such as the shrimp and other small invertebrates that it eats, the water salinity, and the air temperature.

Model Draw a model of your habitat. Think of all the places that you regularly visit and the people you interact with, and include those in your model.

Many species live in the same habitat, but each species occupies a different ecological niche. An ecological niche contains all the physical, chemical, and biological factors that a species needs to survive and reproduce.

The factors that make up a species' niche include the following:

Food sources The type of food a species eats, how a species competes with others for food, and where it fits in the food web are all part of a species' niche.

Abiotic conditions A niche includes the range of conditions such as air temperature and amount of water that a species can tolerate.

Behavior The time of day a species is active and where and when it feeds and reproduces also are factors in the niche of a species.

An ecosystem is a collection of habitats. The organisms that occupy these habitats have separate niches, but the niches have certain abiotic and biotic factors in common. Think of a habitat as *where* a species lives and a niche as *how* the species lives within its habitat.

Explain How is a niche different from a habitat?

Relationships in Ecosystems

Each organism in an ecosystem interacts with other organisms as it goes about its daily activities. The flamingos and other animals prey on the lagoon's plankton, invertebrate, and fish populations for food, and they in turn are food for larger carnivores. Plants compete with one another for space, water, and nutrients. Still other organisms form interspecies relationships to provide or gain shelter, get protection, or find food. These interspecies interactions often benefit only one of the organisms in the relationship, but sometimes both organisms benefit.

FIGURE 3: The frog is the predator in this relationship.

Predation and Competition

Predation is the process by which one organism, the predator, captures and feeds upon another organism, the prey. The frog in Figure 3 is the predator, and the insect is its prey. However, if a snake slithered by, the frog might become its prey. Predation is not limited to carnivores—herbivores that seek out and eat parts of living plants are considered predators, too. The relationship between predator and prey is important for energy transfer in food chains.

Analyze Are humans predators in their ecosystem? Explain your answer.

Competition occurs when two organisms compete for the same limited resource, be it food, shelter, water, space, or any other biotic or abiotic factor that both organisms need to survive. Whenever two organisms need the same resource in a habitat, they must compete for it. Competition can occur between members of different species or between members of the same species, such as the blue jays that are fighting over a peanut in Figure 4.

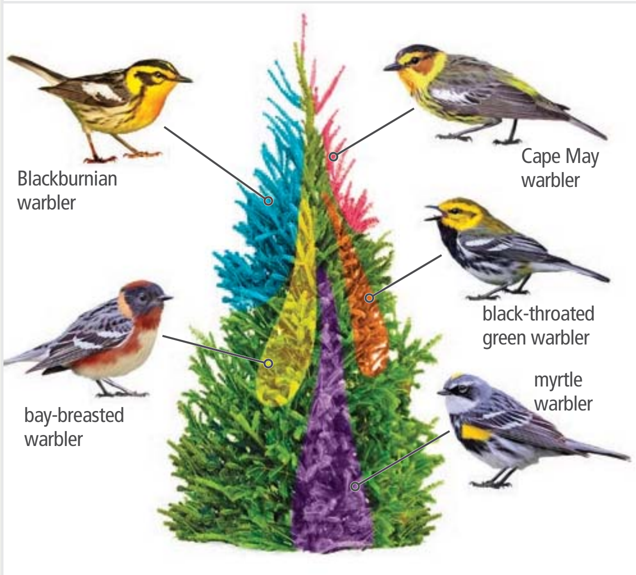
FIGURE 4: Two blue jays compete for a food source.

Collaborate With a partner, think of at least two reasons why an organism might compete with another organism of the same species for a limited resource. Explain why two organisms would compete for these limited resources rather than share them.

Competition for limited resources in an ecosystem can be like a game of musical chairs—not enough chairs are available for everyone and each chair seats only one person. When the music stops, one person will be competitively blocked from the chairs by the remaining players.

Stability and Change

FIGURE 5: These songbirds eat insects commonly found in spruce, pine, and fir trees.



In ecology, the principle of competitive exclusion states that when two species compete for the same resources, one species will be better able to get the resources in the niche. The unsuccessful species will be pushed into another niche or become extinct. The result is that both species end up in distinctive niches so they do not compete for the same limited resource.

Analyze Use the diagram in Figure 5 to answer the following questions.

1. What does this diagram show, and how does it relate to the competitive exclusion principle?
2. Suppose the tip of the spruce tree was broken off during a wind storm. How might the birds be affected by the loss of the uppermost niche in the tree?

Symbiosis

Symbiosis is a close ecological relationship between two or more organisms of different species that live in direct contact with one another. There are three major types of symbiosis: mutualism, commensalism, and parasitism.

FIGURE 6: Symbiotic relationships

Mutualism
Mutualism occurs when both species benefit from the relationship. Pollination, in which an insect pollinates a plant, is a common example of mutualism. Other examples of mutualism include species providing food or shelter, aiding in reproduction, or providing protection for one another. A shrimp cleaning the mouth of a fish, shown at left, is an example of mutualism.

Commensalism
Commensalism is a relationship between two organisms in which one organism receives an ecological benefit from the other, while the other neither benefits nor is harmed. A commensal relationship between two species might involve one organism providing transportation or a home for the other without harm or benefit to itself. As shown at left, an egret eating the insects stirred up by a cow as it moves and feeds on grass is an example of commensalism. The cow neither benefits nor is harmed by the actions of the egret.

Parasitism
Parasitism is a relationship in which one of the organisms benefits while the other one is harmed. Unlike a predator, which kills and eats its prey, a parasite benefits by keeping its host alive for days or even years. The needs of the parasite are met by the victim of the parasite, called the host. The host's health often suffers due to blood or nutrient loss. Galls made by insects on the leaves of plants are an example of parasitism, as shown here.

Gather Evidence What do the shrimp and the fish each gain from this ecological relationship? Why doesn't the fish eat the shrimp?

Explain How might symbiosis help the stability of an ecosystem? How might it hurt ecosystem stability?

Biodiversity in Ecosystems

FIGURE 7: Coral reefs are marine ecosystems where many different species live.

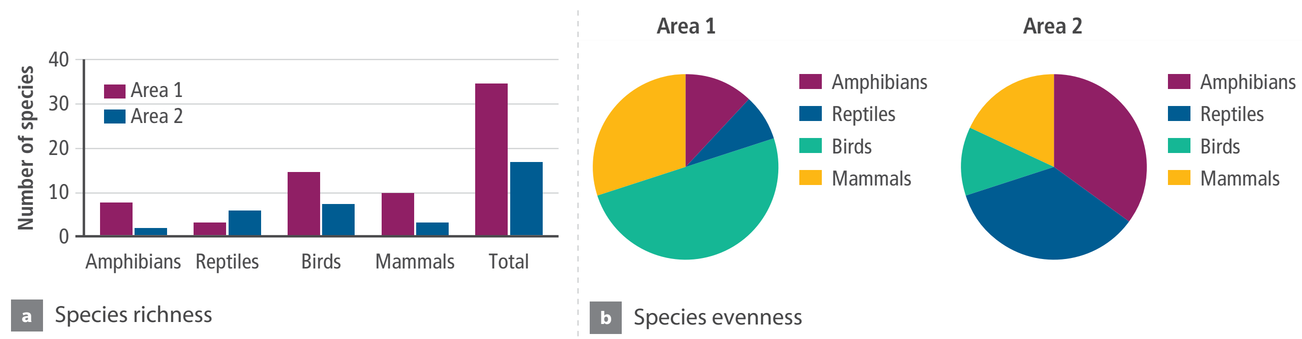
Coral reefs make up a small percentage of marine habitats, but contain most of the oceans' species diversity. The more diverse an ecosystem is, the more likely it is to remain stable over the long term. If a disturbance, such as pollution or a fire, affects an ecosystem, recovery can happen more quickly if that ecosystem has more biodiversity.

Biodiversity

The complexity of an ecosystem indicates its biodiversity level. Biodiversity refers to the variety of species within an ecosystem. Note that biodiversity measures the number of different species, not the number of individual organisms living in an area. An area with a high level of biodiversity, such as a coral reef, has a large assortment of species living near one another. Biodiversity depends on many factors, such as moisture and temperature. The complex relationships in ecosystems mean that a change in a single biotic or abiotic factor can have a variety of effects, both small and large, on many different species.

Data Analysis

FIGURE 8: Ecologists analyze species richness (left) and species evenness (right) to evaluate ecosystem biodiversity.



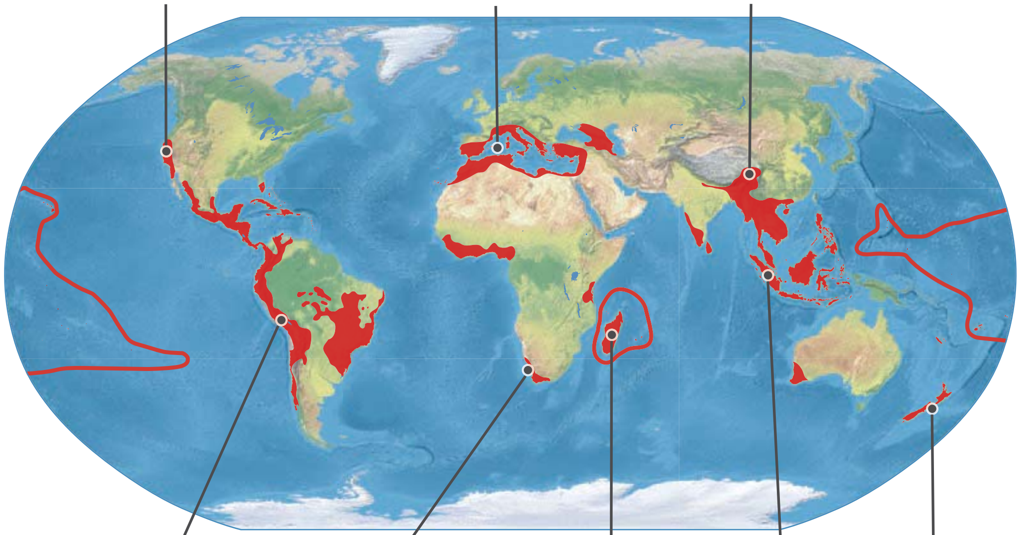
There are many different ways to measure biodiversity in an area. Two factors that ecologists often use are species richness and species evenness. Species richness is the number of species per sample of an area. Areas with a high number of different species have high species richness and therefore high biodiversity. Species evenness measures the abundance of different species that make up the species richness. Species evenness considers the relative distribution of the numbers of species in an ecosystem.

Explain Use the graphs in Figure 8 to answer the following questions:

1. What might happen if a new bird species arrived in Area 1?
2. How could this affect the species richness and species evenness in Area 1?
3. What conclusions can you draw about species richness and species evenness between the two areas?

FIGURE 9: Scientists have identified over 30 biodiversity hot spots around the world.

Explore Online



A biodiversity hot spot is an area with a particularly high level of biodiversity. Figure 9 shows a global map of biodiversity hot spots. These locations often contain species that are found nowhere else in the world. One hot spot located in North America is the California Floristic Province, an area with a Mediterranean-like climate that is home to giant sequoia and coastal redwood trees.

Scientists are currently working to protect several biodiversity hot spots. Preserving these areas helps to prevent species from going extinct and protects the ecosystem as a whole. Maintaining as much biodiversity as possible makes the entire biosphere healthier and provides a more stable habitat for plants, animals, and other species. These areas also are important, because they may hold clues to new medicines and new resources and may further our understanding of the biosphere.

Analyze Biodiversity hot spots are found around the world. Why can scientists not come up with a single solution to protect all of these areas?

Engineering

Building Artificial Coral Reefs

Earth's coral reefs are critical for the stability of marine ecosystems. Unfortunately, many are classified as threatened because of the effects of human activity. Living corals depend on the limestone deposited by their predecessors to get the minerals necessary to build their own bodies. However, the limestone is being dissolved from existing reefs due to increased ocean acidity caused by climate change. Marine ecologists are now combating this destruction by sinking artificial reefs, such as the one shown in Figure 10, which uses electrical currents to attract the limestone deposits needed by growing coral.

FIGURE 10: Artificial reef

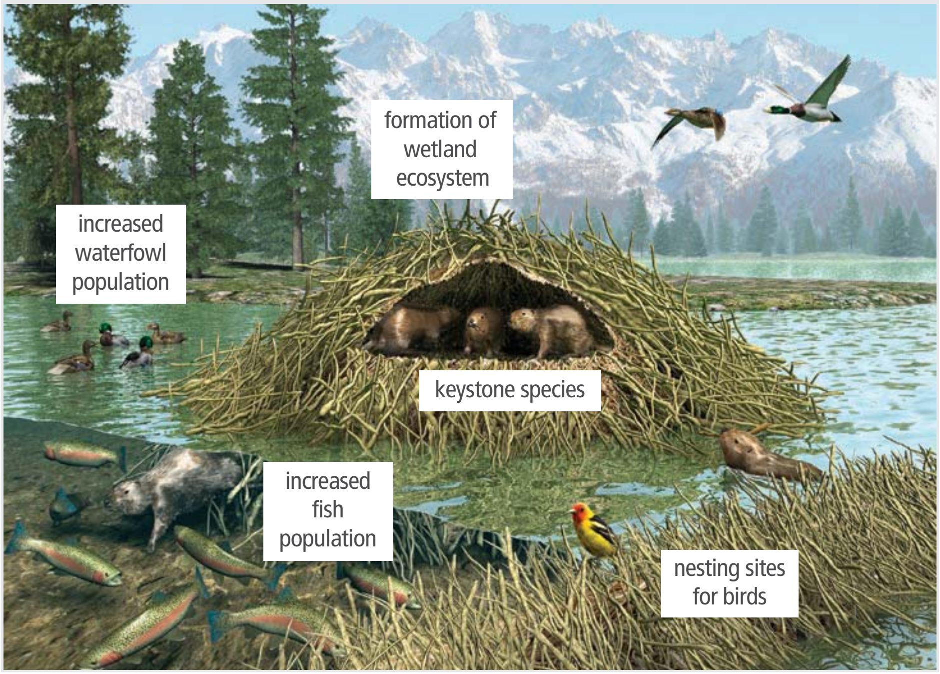
Gather Evidence What is the relationship between biodiversity and ecosystem stability? How do artificial reefs affect a marine ecosystem's stability?

Keystone Species

Sometimes a single species has an especially strong effect on an entire ecosystem. This species is called a keystone species. Whatever happens to this species affects all the other species in that ecosystem. For example, when the beavers shown in Figure 11 built their dam across a stream, it turned a terrestrial ecosystem into a freshwater ecosystem. This killed existing plants and forced land animals to move to new territories. The new pond's inhabitants rely on the beavers to maintain the dam. If the beavers are removed, the dam will eventually fail. The pond will drain and over time the land will return to a terrestrial ecosystem, such as a meadow.

Collaborate With a partner, discuss why protecting a keystone species can protect a habitat as a whole.

FIGURE 11: Beavers are a keystone species that make and maintain pond ecosystems.



Factors That Affect Biodiversity

FIGURE 12: Many farmers use pesticides to control insects and weeds to increase the amount of harvested crops.

Many factors can reduce biodiversity. Human activities can reduce it very quickly. Humans need food, and much of that food comes from plants, which requires large areas of land to be cleared to make fields to grow crops. Developing agricultural land removes most of the native plant and animal species in a region and replaces them with one or only a few species that are managed as crops. In addition, pesticide use can negatively affect any remaining native organisms. Biodiversity also is lost when land is cleared for human housing and industrial sites.

Introduction of new plants and animals into ecosystems is another serious issue. These species can reduce biodiversity by preying on native species or outcompeting native species for resources, such as food or shelter.

Explain How does a natural phenomenon, such as the eruption of a volcano on an oceanic island, affect biodiversity? Will the biodiversity that returns to the island be the same as it was before?

Disturbances in Ecosystems

An ecosystem is a complex web of relationships and interactions among organisms in their environment. In general, an ecosystem can remain relatively constant over a long time under stable conditions. However, a change in one or more of the biotic or abiotic factors can disrupt the ecosystem and cause change. A change brought about by a physical, chemical, or biological agent that impacts population size or community structure is called a *disturbance*. Disturbances can occur over short or long time frames. The type and size of the disturbance can affect how the ecosystem changes. For example, a tsunami wave rapidly disrupts a coastal ecosystem by flooding habitats and saturating soil with salt.

FIGURE 13: A tsunami causes devastating flooding.

Analyze How might the carrying capacity of a coastal ecosystem change as the result of a tsunami? Explain using one or more examples.

Natural Disturbances

Natural disturbances refer to the damage or destruction to ecosystems caused by nature. Tornadoes, volcanic eruptions, and lightning-caused forest fires are all examples of natural disturbances. These disturbances may affect only a small area. For example, a tornado causes a natural disturbance in a relatively narrow path where it touches down, while a forest fire or flood can cause natural disturbances that cover many square miles.

Human-Caused Disturbances

People live in the environment, and many of our actions affect ecosystems. Human-caused disturbances include human settlements, agriculture, air and water pollution, clear-cutting forests, and mining. Like natural disturbances, human-caused disturbances can affect both small and large areas. They destroy habitats, wipe out producers, and contribute to a loss of biodiversity. However, some disturbances are unique to humans, because the changes are more or less permanent. For example, roads and highways can permanently fragment an ecosystem, changing the way populations of species interact with their habitat and altering the way abiotic factors cycle through an ecosystem.

FIGURE 14: Clear-cutting a forest means removing all the trees.

Collaborate With a partner, discuss why foresters might choose to clear-cut a forest rather than use another method to get wood for human needs. What are the pros and cons of clear-cutting?

Ecosystem Stability

Disturbances alter ecosystems, but if an ecosystem is relatively stable over time, it can usually recover from a disturbance at a faster rate, adapting to or reversing any changes. How well an ecosystem rebounds, however, is determined by two factors: its resilience and its resistance.

Explore Online

Language Arts Connection

The Key(stone) to Ecosystem Stability Prepare a presentation describing the effects that your chosen keystone species has on ecosystem stability.

FIGURE 15: This old-growth forest has been stable for many years.

Analyze Old-growth forests have remained undisturbed for hundreds of years or more. From what you see in Figure 15, what are some characteristics of a stable ecosystem?

Ecosystem Resilience

Explore Online

Hands-On Activity

Simulating Fire in a Forest Ecosystem Develop or use an already-existing simulation to examine how fire affects forest species. How might prescribed burns be used to manage the biodiversity in a forest, including threatened or endangered species?

Ecologists define ecosystem resilience as the ability of an ecosystem to recover after it has undergone a disturbance. This means that even though the structure of the ecosystem is affected in some way, the ecosystem can recover quickly and return to functioning as it did before the disturbance. For example, a grassland that has regular fires is considered resilient, because the grasses quickly regrow and the animals return very soon after a fire ends.

The resilience of an ecosystem is determined in part by its level of biodiversity. A complex ecosystem with many populations of species that perform the same function, such as producers, is more resilient than one that has a limited number of species that perform each function. Consider two forests—one a single-species stand of mature pine trees and the other a multispecies stand of old and young conifers. If both stands are impacted by identical severe wind events, the stand of mature pines will be more severely affected by breakage and uprooting than the mixed stand. The mixed stand, with its variety of wood characteristics and ages, will have more trees left after the wind event. It will recover and continue to function as a forest much more quickly than the singles-species stand of pines.

Biodiversity improves the resilience of an ecosystem, but only to a point. Genetic diversity in each species in an ecosystem is also important. Human activities that alter biodiversity or increase the rate of change, such as using pesticides and antibiotics, fishing, and destroying rain forests, reduce genetic diversity. A reduction in genetic diversity decreases the chance that populations can adapt to abiotic disturbances in an ecosystem.

Predict What similarities would you expect to find in a highly resilient ecosystem?

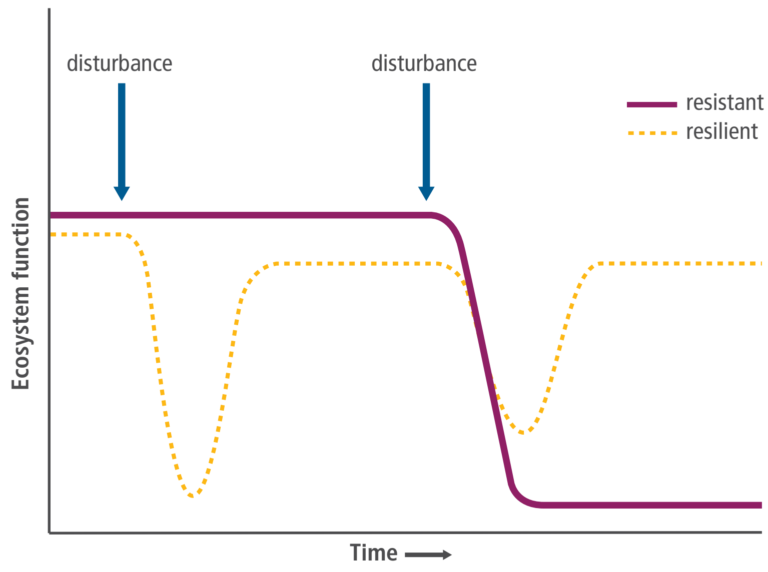
Ecosystem Resistance

Resistance is the ability of an ecosystem to resist change from a disturbance. Some ecosystems are highly resistant to change while others have little resistance. Highly resistant ecosystems remain essentially unchanged when a disturbance occurs.

Even the most resistant ecosystem can be stressed beyond its ability to recover. In the past, the forests along the ridges of the Appalachian Mountains have recovered from repeated wind, snow, and wildfire damage but are now slowly dying from the effects of acid rain.

Resistance and Resilience in Ecosystems

FIGURE 16: Resistant ecosystems remain unchanged after a disturbance occurs, while a resilient ecosystem quickly rebounds. This graph shows a simplified version of how ecosystem function might respond to disturbances in resistant versus resilient ecosystems.



Resistant ecosystems initially show little impact caused by disturbances. However, if disturbances become too intense, ecosystem structure and function may be severely impacted. As shown in Figure 16, after a second disturbance, the example resistant ecosystem is not able to recover as easily. A resilient ecosystem is often immediately impacted by even low-intensity disturbances but can quickly recover structurally and functionally to levels approaching the conditions before the disturbance occurred.

Explain The concepts of resistance and resilience shown in the graph can be applied to other situations too. Thanks to scientific advances and technology, we now have many medicines to treat diseases caused by pathogens. Does this make humans more or less resilient as a species? Does it make humans more or less resistant? Explain your reasoning.

Gather Evidence Think back to the volcanic eruption on the island. Once the lava cooled, plants began to grow. Is this an example of a stable ecosystem? Use evidence from the discussion of resilient and resistant ecosystems to support your answer.

Ecological Succession

The area surrounding the Kilauea volcano on the island of Hawaii is a prime example of what happens when an ecosystem undergoes a devastating disturbance. What was once a lush tropical ecosystem is now covered in bare volcanic rock. Over time, this new volcanic rock will undergo a series of changes. Ecological succession is the sequence of biotic changes that restore a damaged community or create a community in a previously uninhabited area. Two types of ecological succession occur: primary and secondary.

Primary Succession

Analyze Where do pioneer species come from?

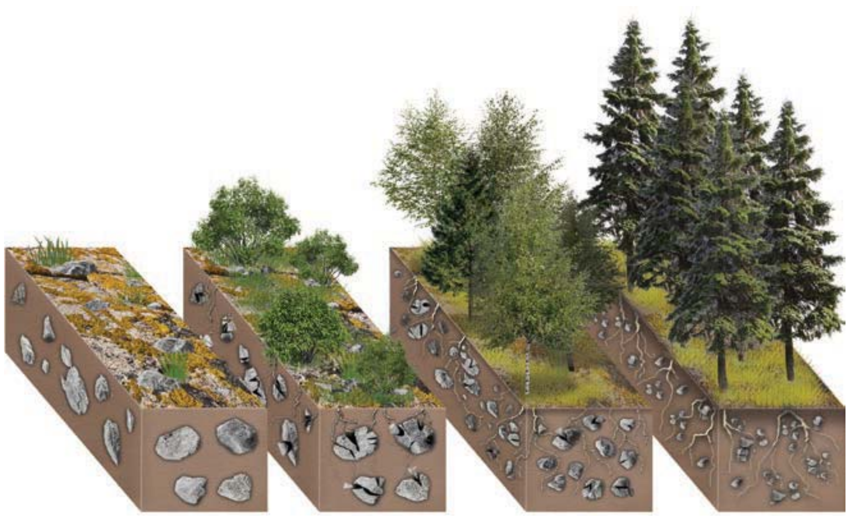
Primary succession, shown in Figure 17, is the establishment and development of an ecosystem in an area that was previously uninhabited, usually a bare rock surface. Melting glaciers, volcanic eruptions, and landslides all begin the process of primary succession. The first organisms that move into this area are called *pioneer species*. These organisms, such as mosses and lichens, break down solid rock into smaller pieces. Once pioneer species have made soil, plants such as grasses can begin to grow. Over time, shrubs and trees replace the grasses to form a forest. This process continues until a climax community is established.

Explore Online

Hands-On Lab

Using GPS in Ecological Surveys Perform a survey by collecting and recording samples of plant life from a given area of land. Find and map their exact location using GPS, and analyze the data.

FIGURE 17: It can take hundreds of years to establish a climax community. This diagram shows the process of primary succession in a boreal forest.



a **0–15 years** Moss, lichens, grasses

b **15–80 years** Shrubs, cottonwoods, alder thicket

c **80–115 years** Transition to forest, alder, spruce

d **115–200 years** Hemlock-spruce forest

Explain Do you think tall trees are the final stage of primary succession in every biome? Explain your answer.

Secondary Succession

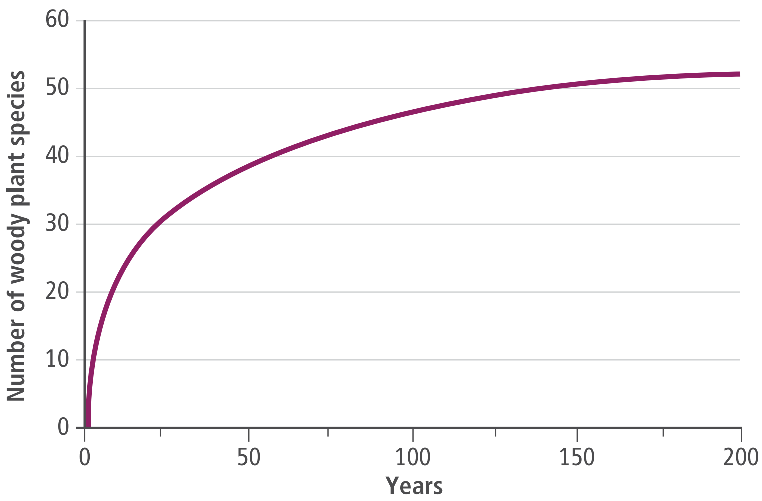
Secondary succession is the reestablishment of an ecosystem in an area where the soil was left intact, such as after a fire or flood. Because soil is already present in the ecosystem, secondary succession reaches the climax community stage more rapidly than primary succession. The process of regrowth is begun by the plants, seeds, and other organisms that remain after the disturbance occurs.

As with primary succession, biodiversity of the ecosystem typically increases as secondary succession progresses. One reason for increased biodiversity is the return of animals as the plant population grows. In addition, animals bring in seeds from plants in other ecosystems on their fur and in their waste, which will establish new plant populations if conditions are favorable for growth.

Model Make a model that shows the difference between primary and secondary succession. Make sure your model explains how long each step takes and why.

Data Analysis

FIGURE 18: The amount of species richness in an ecosystem is related to its stage of succession.



Analyze Think about how an ecosystem changes during secondary succession. Refer to the graph in Figure 18 to answer the following questions.

1. When does species richness increase at the fastest rate? Why is this possible?
2. Why does the species richness not continue to rise over time? Explain.

Succession is an ongoing process. Even after the climax community is reestablished, changes continue to occur. Small disturbances, such as a tree falling, restart the process. For this reason, an ecosystem is generally never really permanently established—the processes of succession are always causing changes in an ecosystem.

Gather Evidence How does ecological succession affect biodiversity? Use evidence gathered from this lesson to support your claims.

Language Arts Connection

FIGURE 19: A specially designed air tanker drops a load of fire retardant to slow the progress of a California wildfire.

Should Forest Fires Be Suppressed?

Forest fires can cause considerable damage to forest ecosystems; therefore, wildland firefighters work hard to contain and put out forest fires. They use heavy equipment, such as bulldozers, to stop the spread of wildfires. Sometimes airplanes and helicopters carrying water or fire retardant are also used to put out the fires, as shown in Figure 19.

Fire is a natural part of many ecosystems. It cycles nutrients back into the soil from plants. In some forests, shrubs growing underneath the trees are naturally removed by cyclically occurring fires. In most cases, these fires leave the trees and other organisms living in the ecosystem unharmed. With increased efforts to prevent and stop forest fires, shrubs and other understory species grow thick. When a fire does occur, it burns extremely hot and catches the trees on fire. This can have a catastrophic impact on the forest as a whole.

After major forest fires in the late 1800s, early conservationists became concerned about the effect of wildfire on future timber supplies. In 1905, they convinced the United States government to establish the U.S. Forest Service. This agency developed fire protection practices in an effort to conserve what came to be known as national forests.

Just five years later, a series of fires burned 3 million acres over a three-state region. The "Big Blowup," as it was called, changed national thinking about fire management. State and Federal forest officials decided the best way to protect the national forests was to completely suppress any and all wildfires. To that end, policies were enacted that were designed to stop fires completely when possible and put out any fire that did occur as rapidly as possible.

At the time, conservationists and foresters did not understand fire's ecological importance to a forest ecosystem. They believed all fire was bad, because it damaged timber, an economically important resource. As a result, they banned the use of fire to clear underbrush and improve soil. They also constructed roads, watchtowers, and ranger stations to make it easier to detect and reach any forest fire quickly.

In the 1930s, a firefighter corps was established that could be sent anywhere a forest fire occurred. As technology advanced, airplanes and helicopters were added to the ground equipment to drop firefighters and fire-suppression chemicals wherever they were needed. Today, the National Interagency Fire Center (NIFC) coordinates and supports the deployment, training, and certification of firefighters, equipment, and support staff nationwide.

Through continued research, scientists found that fire can actually be helpful to some ecosystems, and Forest Service officials began to realize that fire suppression led to a buildup of fuel that made fires much more hazardous when they did break out. This led to a change in policy that allowed for prescribed burns to manage fuel loads in certain forests and other wildlands, based on the ecological needs of the area.

How do officials decide where and when a wildfire should be fought instead of being allowed to burn? Ecosystem characteristics play a major role in these decisions. For example, stands of Rocky Mountain lodgepole pines need regular exposure to fires severe and intense enough to wipe out the stand and allow a new one to grow in its place. Other plants depend on fire as part of their reproductive strategies. For example, the cones from sequoia trees need fire to open and release their seeds. Fire also exposes bare soil where the seeds can take root and opens the forest canopy, allowing light to reach the seedlings, which helps them grow. On the other hand, wildfires in zones near human populations require active suppression to protect life and property. As human development takes over what were once wild spaces, the potential for widespread catastrophe increases.

Climate affects fire management policy as well. Naturally occurring events such as the yearly Santa Ana winds that blow along coastal Southern California and northern Baja California contribute to the outbreak and spread of wildfires. Lightning strikes, heat waves, and droughts also increase the occurrence of wildfires. Climate change is beginning to increase the severity of weather phenomena that contribute to wildfires. These fire events increase the amount of stored carbon released into the atmosphere. All of these factors require officials to be flexible in their policy decisions.

Lastly, cost figures into the development of fire management policies. Fighting wildfires is expensive in terms of hours worked, transportation, and equipment costs. Wildfires also cause economic damage to communities and endanger lives. Officials must weigh these factors when determining whether to practice fire-suppression policies.

FIGURE 20: Forest fires can cause significant economic damage to cities and towns in their path.

Language Arts Connection

Some policymakers think that natural wildfires should be allowed to burn or that controlled burns should be used as a forestry management tool. Others argue that the risk of letting fires burn or starting controlled burns pose a hazard to the forests and people. Select a position on whether or not to allow controlled burns. Research to learn about the pros and cons of controlled burns.

Gather information and write a one-page position paper. Your paper should discuss your viewpoint and cite evidence from your research to support your claims.

After completing your research and writing your position paper, you will take part in a classroom debate. In the debate, you will have an opportunity to state and defend your position using the information you gathered in your research. Be sure to listen to the students who agree with your position and those who disagree as you make your own arguments.

CASE STUDY: SECONDARY SUCCESSION AT MT. ST. HELENS | SUCCESSION IN DIFFERENT ECOSYSTEMS | THE KEY(STONE) TO ECOSYSTEM STABILITY | Go online to choose one of these other paths.

Lesson Self-Check

CAN YOU EXPLAIN IT?

FIGURE 21: A lone seedling begins the process of colonizing a field of lava.

Volcanic eruptions play an important role in the formation of new ecosystems, but the resulting lava flows leave behind a hard rock surface that cannot support life. Nevertheless, living things will gradually begin to grow and thrive on this rock surface as it undergoes chemical and physical weathering. Over time, the bare rock will no longer be visible as it becomes covered in soil and plant life.

The Hawaiian Islands began to form more than 70 million years ago following volcanic eruptions in the middle of the Pacific Ocean. As time passed, the process of succession created unique tropical ecosystems. Succession from bare rock to highly diverse vegetation takes a great deal of time. When new eruptions occur, the process of succession begins again, and eventually a stable ecosystem returns.

Explain Refer to the notes in your Evidence Notebook and use what you learned in the lesson about succession to explain how a plant is able to grow in the middle of a lava field.

CHECKPOINTS

Check Your Understanding

1. Which of the following is a characteristic associated with an organism's niche but not with its habitat?

a. climate

b. soil quality

c. place in the food web

d. location within the ecosystem

2. Which of the following are factors in determining the stability of an ecosystem? Choose all that apply.

a. the process by which it recovers after a disturbance

b. the ability to function during a disturbance

c. whether a disturbance is natural or human-made

d. the rate of recovery after a disturbance

e. the level of biodiversity in the ecosystem

3. An epiphyte is a plant that grows on the surface of another plant, such as a tree. It gets water and nutrients from the air and its surroundings instead of from the tree. The tree is unaffected by the epiphyte's presence. What type of relationship does the epiphyte have with the tree? Explain your reasoning.

4. Whenever *Paramecium aurelia* and *Paramecium caudatum* are placed into the same culture and given a constant supply of food under constant conditions, *P. aurelia* will always outcompete *P. caudatum*, which eventually dies off. What factors prevents *P. caudatum* from surviving in this situation?

5. Ecological succession after a disturbance usually takes hundreds of years in the Pacific Northwest. However, succession after the Mount St. Helens eruption in 1980 has progressed much more rapidly, because some plants and animals were in protected areas when the hot ash and pumice fell. What conclusion can you draw about the pace of succession from this example?

6. Use the following terms to complete the statement:
resilient, resistant
If an ecosystem is ____________, it is generally stable unless drastically changed by a disturbance. When a disturbance causes a change, the ecosystem quickly recovers when it is ____________.

7. Ecosystem A and Ecosystem B have the same eight species, but Ecosystem A has a more even distribution of species than Ecosystem B. Which ecosystem is more diverse? Explain your reasoning.

8. Top predators are often keystone species in their habitat. Explain what happens to the biodiversity of an ecosystem when a top predator is deliberately removed from the ecosystem in which it lives.

MAKE YOUR OWN STUDY GUIDE

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

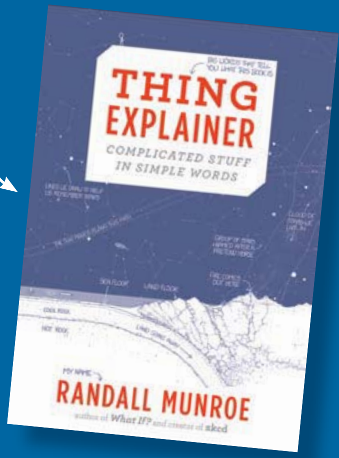
Within an ecosystem, organisms interact with each other and with their environment. The stability of the ecosystem is determined by its biodiversity, resilience, and resistance to change.

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 ecosystem interactions can be used to analyze ecosystem dynamics and predict how conservation efforts will affect the stability of these ecosystems.

A BOOK EXPLAINING COMPLEX IDEAS USING ONLY THE 1,000 MOST COMMON WORDS

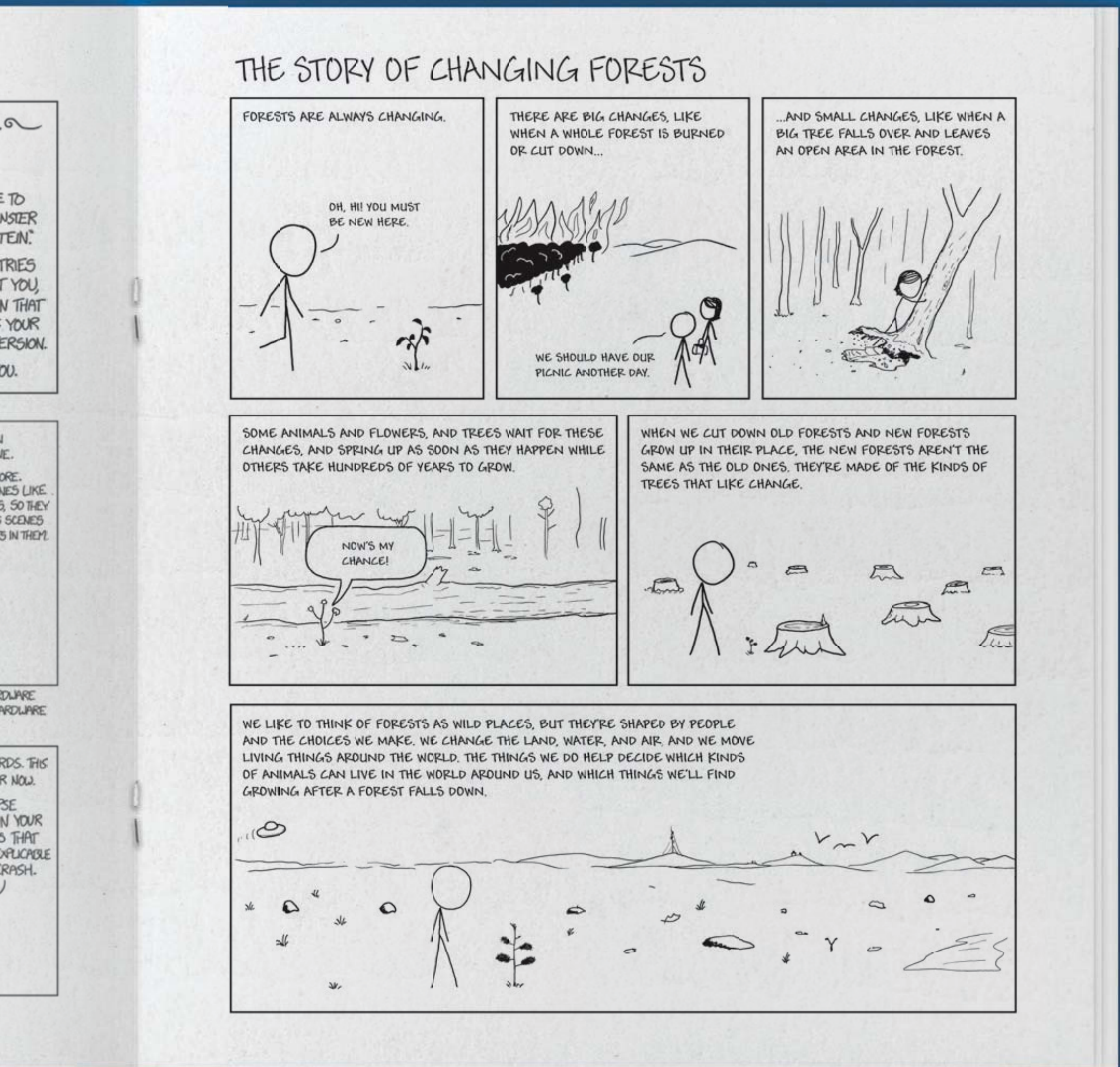


RANDALL MUNROE
XKCD.COM

HOW FORESTS COME BACK

How trees and flowers and animals fill in the land again after a big change

After a disturbance in an ecosystem, biotic changes regenerate the damaged community or create a new community in a previously uninhabited area. Take a look at this process of change and rebirth.



THINGS THAT HAPPEN TO FORESTS

Sometimes, big things happen to forests that clear out lots of the old trees and animals that live there. When these things happen, lots of new trees and flowers come in to fill in the space. After a while, big trees can grow back.

Here are a few of the things that can happen to forests:

FIRE

In some forests, there are fires every so often that burn lots of the plants and trees, along with dead sticks and leaves lying on the ground.

PEOPLE

People cut down forests to make room for stuff or because they want to use the wood. Most of Earth's old forests have been cut down over the years.

WIND

When there's a really big storm, wind can push over lots of trees, especially if the storm happens when the trees have leaves on them.

GETTING EATEN

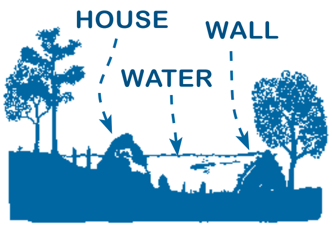
Most animals that eat trees get eaten by other things. If something that eats trees moves to a new part of the world where nothing eats it, it can eat whole forests.

SMALL HOLES IN THE FOREST

Some forests have little animals that like to build their houses in pools. If they can't find a pool to use, they make a new one by cutting down trees and building a wall across the river.

The water covers part of the forest, and the trees that are covered with water die. When the animals move away, the wall falls apart.

When the water in the pool goes away, it leaves an open area among the trees. Over the years, this area fills with green things and becomes a forest again.



BIGGER PROBLEMS

Life doesn't just come from nowhere. When forests are cleared and grow back, some of the new trees grow from parts in the ground that are still alive. Other green things move in from the edges or are carried by the wind or birds.

But if there's a really big change, there might not be any life left in the area to grow back. Sometimes, on land out in the sea, hot fire comes out of the ground and the rocks get hot and run like water. If this happens, nothing grows back until new life is carried there from across the sea.

A FOREST AFTER A FIRE

WHAT STARTS FIRES?

Many forest fires are caused by people. Sometimes, people drop burning things on the ground and forget about them, or they start fires to sit around and then don't put them out.

Other fires start without help from people. Most of those are caused by flashes of power from big storms, but some are caused by hot rocks that come out of holes in the tops of mountains.

SPACE ROCKS

Big rocks falling from space can start fires, but that doesn't happen very often. As far as we know, there haven't been any of these fires since people started writing down things that happened.

FIRE STARTER

Fires aren't usually started by people who are bad at flying space boats, but it could happen!

Some fires burn the dead leaves and sticks on the ground but don't really bother the big trees.

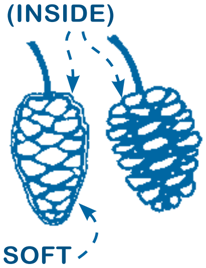
These small fires can be good for a forest, because they burn away the leaves and sticks before too many of them pile up.

If there are a lot of dry sticks or dead branches on the ground, fires can get big and hot. These fires can spread to the tops of trees and burn down forests.

If it goes a long time without raining, all the dry stuff makes fires bigger and hotter.

TREE EGGS

These things fall off of trees. Then they open up and new trees grow out of them.



Fires clear away the tall trees that block light from the ground. Some trees make tree eggs that stay closed until there's a fire, so they can get lots of light and grow quickly.

These tree eggs are covered in a layer of clear stuff that keeps them from opening up. When a tree egg gets hot in a fire, the clear stuff gets soft and falls off, the egg opens up, and the tree starts to grow.

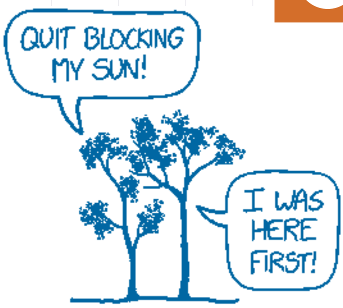
Go online for more about *Thing Explainer*.

TREES THAT DON'T MIND FIRE

Some trees are good at living through fires. Their strong, thick skin keeps them safe from heat, and some keep most of their branches near the top to keep their leaves away from the burning stuff on the ground.

GREEN THINGS RETURN

The first things to grow up after a fire are grasses and flowers, like the things you pull up from your garden. They're good at spreading and grow very fast.



TREE FIGHTS

Some trees try to be the first to grow up in the clear space after a fire. If a tree grows taller than the ones around it, it can block the sun's light from the other trees and keep more light for itself.

BIRDS DROPPING TREE EGGS AS THEY FLY AROUND

HIDING TREES

Some trees and green things live through fire even if their top parts burn down. They can grow back up out of the parts left in the ground.

FAST TREES

In the first twenty or thirty years after the forest is cleared away, fast trees grow up. They block the sun's light from reaching the ground, which makes the grasses and small plants die off. These are young forests.

BIRDS THAT EAT SMALL ANIMALS

Some birds that eat small animals like to fly over open fields like this or sit in trees near the edge. When they see something running in the grass, they try to catch it.

Since these birds like areas where forests meet open areas, they're often spotted in trees by the side of big roads.

BIRDS THAT EAT OTHER BIRDS (HIDING)

Different animals like different kinds of forest. In some areas, as the trees get bigger, different kinds of birds move in. Some birds are good at flying through trees to catch other birds. Since these birds usually stay away from the edges of forests, people don't see them as often.

SLOW TREES

After the first trees grow up, new kinds of trees start to grow. These newer trees grow slowly, and they don't need as much sun, so they can grow up in the shadows of the faster trees.

OLD FORESTS

Slow trees grow up and take the place of the fast trees. This takes a very long time—longer than a person's life.

Forests that are many times older than the oldest humans are special. They have different kinds of trees and animals than young forests have. Many of those older forests have been cut down, and some people are trying to save the ones that are left.

Environmental Science Connection

Feral Hogs Feral hogs are descendants of domesticated hogs that escaped captivity. Feral hogs are able to survive in many ecosystems due to the lack of natural predators and their diverse foraging habits. Feral hogs change abiotic factors in ecosystems, such as soil structure and levels of erosion. They also change biotic factors in ecosystems, such as disrupting native plant communities and competing for resources with organisms in similar niches.

Using library and Internet resources, research the feral hog epidemic in the United States. Create a public service announcement that will inform landowners about the scale of the feral hog epidemic and the potential impacts to the environment, including changes to populations and ecosystems.

FIGURE 1: Feral hogs can change ecosystems.

Art Connection

Conservation Photography Have you ever heard the saying, "A picture is worth a thousand words"? Conservation photographers embrace this statement when they use pictures to highlight environmental problems. Candid and staged images are used to invoke a response in the public and to advocate for conservation outcomes. When devastating changes in ecosystems are documented in visual ways, it can strengthen public support and involvement in critical environmental issues.

What is the difference between nature photography and conservation photography? Using library and Internet resources, research the field of conservation photography and the work of a particular conservation photographer. Prepare a multimedia presentation that explains the purpose of conservation photography and introduces a photographer you researched, selections of his or her work, and explanations of the conservation issues that the photographer highlights.

FIGURE 2: This photograph could be used to highlight the impact of global warming on polar bear populations.

Social Studies Connection

Environmental History Human impacts on the environment during the last several centuries have been extensively studied and documented. It is clear that humans have changed and destabilized many modern ecosystems. There is also evidence that ancient peoples, such as the Maya, the Nazca, and the Rapa Nui of Easter Island, changed the landscape in dramatic ways. These changes may not have been on the scale of modern human impacts, but the changes may have resulted in destabilization of ecosystems that led to the downfall of these civilizations.

Using library and Internet resources, research an example of an ancient society whose collapse may be linked to human impacts on the environment. Write a report that provides a brief background on the civilization and evaluates the claims and evidence that the environmental changes led to the disappearance of the society. Include an illustration of the potential impacts the society had on the environment with a model, graph, map, or other method.

FIGURE 3: Ruins of the Mayan Civilization.

SYNTHESIZE THE UNIT

In your Evidence Notebook, make a concept map, graphic organizer, or outline using the Study Guides you made for each lesson in this unit. Be sure to use evidence to support your claims.

When synthesizing individual information, remember to follow these general steps:

- Find the central idea of each piece of information.
- Think about the relationships between the central ideas.
- Combine the ideas to come up with a new understanding.

DRIVING QUESTIONS

Look back to the Driving Questions from the opening section of this unit. In your Evidence Notebook, review and revise your previous answers to those questions. Use the evidence you gathered and other observations you made throughout the unit to support your claims.

PRACTICE AND REVIEW

1. Over the course of a year, a population of 25 penguins gained 5 penguins through births and lost 3 penguins to death. In addition, 10 adult penguins moved into the population through immigration and 6 adult penguins moved out of the population through emigration. What is the yearly growth rate of this population?

a. 19
b. -8
c. -2
d. 6

2. Which of the following would result from the expansion of a species into a new habitat with no predators and evenly spaced resources? Select all correct answers.

a. logistic growth
b. uniform dispersion
c. exponential growth
d. type III survivorship
e. partial relief from density-dependent limiting factors

3. Which type of interaction is most responsible for energy transfer in a food chain?

a. competition
b. mutualism
c. parasitism
d. predation

4. What is the relationship between population number and carrying capacity in a stable population?

a. The population number matches the carrying capacity exactly through births, deaths, immigrations, and emigrations.
b. The population number oscillates around the carrying capacity as resources and population growth rates change slightly over time.
c. The carrying capacity and population number increase when resources are scarce and decrease when resources are abundant.
d. Carrying capacity and population numbers are inversely proportional. An increase in carrying capacity will be accompanied by a decrease in population numbers.

5. An invasive species moves into three niches that were once occupied by three different native species and outcompetes the native species, producing larger population numbers than the three native species combined. What happens to the biodiversity of the ecosystem?

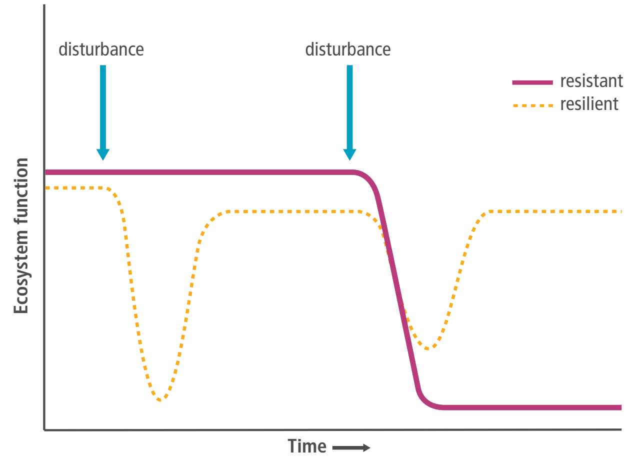
a. Biodiversity increases because the number of individuals increases.
b. Biodiversity decreases because only native species count toward biodiversity in an area.
c. Biodiversity remains the same because the same ecological niches are still being filled.
d. Biodiversity decreases because the number of species decreases.

Ecosystem A is resistant to periodic small-scale floods. Ecosystem B displays resilience to small and large floods. A small flood occurred as a disturbance in both ecosystems, followed by a larger flood. The graph indicates the general reaction of the two ecosystems to the disturbances.

Use Figure 4 to answer Questions 6–8.

Ecosystem Resilience and Resistance

FIGURE 4: Resistance and Resilience in Ecosystems



Source: ©Dr. Jeremy P. Stovall

6. How does succession relate to the decrease in ecosystem function shown in the graph?

a. Decreases in ecosystem function represent the ecosystem being reset to an earlier successional state.

b. Decreases in ecosystem function represent the ecosystem progressing through succession back toward a climax community.

c. Climax communities cause decreases in ecosystem function as types of species and population numbers stabilize.

d. Succession ends when ecosystem function decreases.

7. Which ecosystem would experience more periods of exponential growth after disturbances? Explain your answer.

8. Which characteristics would make Ecosystem B more stable? Select all correct answers.

a. resilient tertiary consumers

b. resilient primary producers

c. high level of biodiversity

d. early successional state

9. What type of ecosystem would be most affected by a sequence of widespread, heavy rainfall that leads to significant regional flooding over the course of several months?

a. resilient ecosystem

b. resistant ecosystem

c. both resilient and resistant ecosystems

d. neither resilient nor resistant ecosystems

10. A limiting factor keeps population size down and can be density-dependent or density-independent. Which of these is the best explanation for why a disease outbreak is considered a density-dependent limiting factor?

a. Disease will only affect population size if the population has a very low density.

b. Disease will spread at the same rate throughout the population, regardless of population density.

c. Disease spreads more readily in a population with closely packed individuals.

d. Disease will not spread if individuals are evenly dispersed in their environment.

UNIT PROJECT

Return to your unit project. Prepare your research and materials into a presentation to share with the class. In your final presentation, evaluate the strength of your hypothesis, data, analysis, and conclusions.

Remember these tips while evaluating:

- Was your hypothesis supported by your data?
- Look at the empirical evidence gathered from your wetland model—evidence based on observations and data. Does the evidence support your claim and reasoning regarding the impact of wetlands on populations and ecosystems?
- Consider if the evidence and explanation are logical. Does your research contradict any evidence you have seen?

Analyzing Red Squirrel Population Dynamics

The Mount Graham red squirrel (*Tamiasciurus hudsonicus grahamensis*) is an endangered red squirrel subspecies that is endemic to the Pinaleño Mountains in southeastern Arizona. Population data for this squirrel is shown in Figure 5. Use this information and independent research to determine population trends for the red squirrel. Investigate whether the red squirrel habitat is declining and what natural or human-caused disturbances may be responsible for fluctuations in the red squirrel population. Based on your investigation, decide whether you think the Mount Graham red squirrel population is resistant or resilient to disturbance.

1. ASK A QUESTION

Develop a set of questions to help guide your research and data analysis. Focus your inquiry on population trends for the Mount Graham red squirrel, how those trends relate to habitat loss, and how the causes of the habitat decline are affecting the red squirrel population.

2. CONDUCT RESEARCH

Investigate the Mount Graham red squirrel population. Use library and Internet resources to explore how this species has fared over the last half-century.

3. ANALYZE DATA

Analyze your research and the population data provided. Graph the population data in order to visualize the red squirrel population trends. Is there evidence of disturbances, ecosystem decline, or the resilience or resistance of the squirrel population?

4. CONSTRUCT AN EXPLANATION

Use your analysis to answer your questions and construct an explanation for the changes in the population of the Mount Graham red squirrel and its habitat.

5. COMMUNICATE

Present your findings about the Mount Graham red squirrel and its habitat. Be sure to include whether you think the squirrel population is resilient or resistant to disturbance. Your presentation should include images and data to support your claims.

FIGURE 5: Average population estimates for Mount Graham red squirrels, 1987-2010.

Year	Average population estimates	Year	Average population estimates
1987	242	1999	530
1988	202	2000	484
1989	174	2001	270
1990	275	2002	292
1991	391	2003	293
1992	332	2004	276
1993	375	2005	289
1994	419	2006	285
1995	407	2007	305
1996	381	2008	273
1997	392	2009	259
1998	566	2010	216

Source: U.S. Fish and Wildlife Service. 2011. Draft Recovery Plan for the Mount Graham Red Squirrel (Tamiasciurus hudsonicus grahamensis), First Revision. U.S. Fish and Wildlife Service, Southwest Region, Albuquerque, NM. 85 pp. + Appendices A-D. [September 30, 2016] https://www.fws.gov/southwest/es/arizona/Documents/SpeciesDocs/MGRS/MGRS_dRecov_Plan_Revision_Final_May2011.pdf

CHECK YOUR WORK

A complete presentation should include the following information:

- guiding questions answered in the final presentation
- a graph that shows the population of Mount Graham red squirrels over time
- an explanation of the current status of the squirrel and its habitat, a discussion of disturbances that affected the squirrel population, and if the squirrel population has shown resilience or resistance to disturbance
- images and data that further support your explanation