10.2

Human Impacts on Biodiversity

Healthy prairies contain diverse ecosystems.

CAN YOU EXPLAIN IT?

FIGURE 1: Prescribed burns are a land management technique used to mimic the benefits of a natural fire.

Gather Evidence
As you explore the lesson, gather evidence for why burning an area could result in an increase in biodiversity. Include a list of questions you would ask to learn more about the role of fire in ecosystem structure and function.

A prairie is a natural grassland that supports a wide range of plants and animals. The North American prairies formed in the rain shadow of the Rocky Mountains. These relatively flat grasslands are too moist to become desert ecosystems but too dry for forests to grow. The prairie ecosystems of North America once covered over 68.8 million hectares (170 million acres) of land. This former expanse included short, mixed, and long grass prairies running from present-day Canada through the United States to the Mexican border. Less than 2 percent of native North American prairie remains. Much of the prairie land has been replaced by agriculture.

Prairie ecosystems are adapted to fire and require relatively frequent fire events to function properly. Some estimates place the historical fire return gap at one to five years for North American prairies. Today, the natural fire return gap is much longer. Land managers may use prescribed burns to return the historical structure and function to prairie ecosystems.

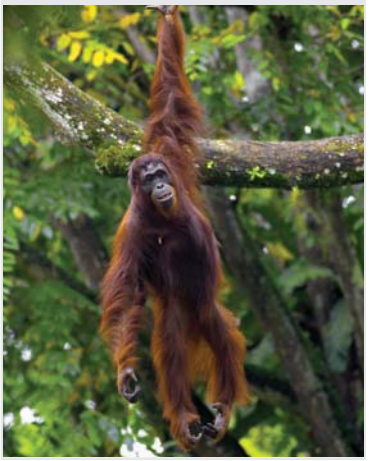
Predict How could burning a prairie increase biodiversity?

Habitat Loss

Earth is currently experiencing a significant loss of biodiversity that is increasingly being recognized as the sixth mass extinction. Habitat loss is the most common cause of decline and extinction in species. Human activities and development that remove natural habitats, such as agriculture, deforestation, and urbanization, all lead to habitat loss and fragmentation.

Collaborate Discuss with a partner how habitat loss could affect biodiversity.

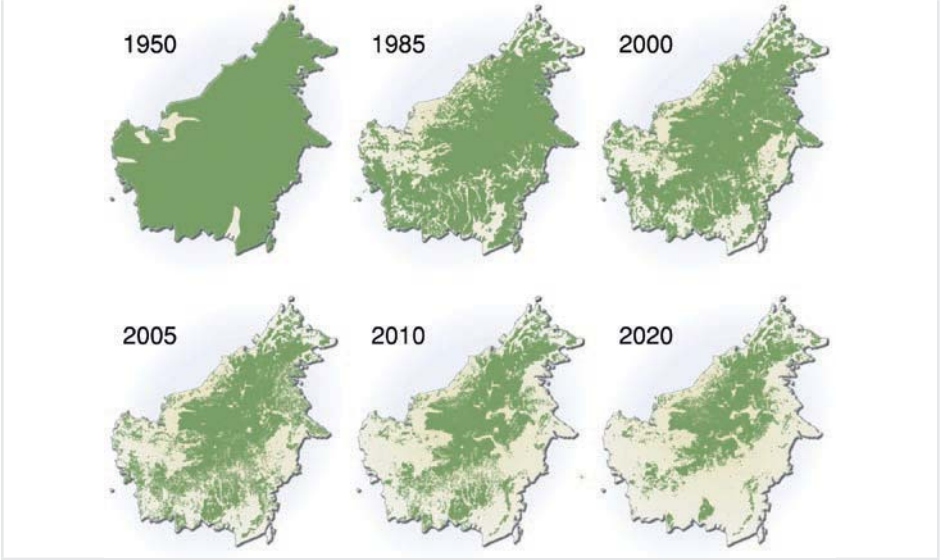
FIGURE 2: Habitat loss threatens orangutan survival.



Clearing Land

The island of Borneo was once widely covered by lowland and mountainous rain forests. Today the island is losing rain forest habitat at an unsustainable rate due to logging, fires, and land clearing for commercial crops. One such crop is oil palms. Palm oil is made from the fruits of the oil palm. It is the most used vegetable oil on the planet and is found in products ranging from cosmetics to packaged foods. The market for palm oil is growing quickly even as the negative effects of palm plantations reach a critical level.

FIGURE 3: Land clearing in Borneo has led to significant habitat loss.



Analyze How can agricultural practices lead to a decrease in biodiversity? Include a list of impacts to ecosystem function and productivity in your answer.

The biggest threat to biodiversity on Borneo is habitat loss. Species such as the Bornean orangutan need rain forest habitat to survive and are therefore particularly sensitive to habitat loss. The number of Bornean orangutans has decreased by over 60 percent since 1950. Poaching also threatens their survival. The Bornean orangutan is critically endangered and may become extinct if enough suitable habitat is not preserved. This species has reached the point that is known as an extinction threshold. If habitat loss continues, the population of Bornean orangutans will not be able to recover and they will become extinct.

FIGURE 4: Roads cause habitat fragmentation.

Habitat Fragmentation

Bornean orangutan habitat is fragmented as land is cleared. Habitat fragmentation occurs when a barrier such as a road or cleared landscape divides a larger habitat into smaller sections, preventing individuals from accessing their full home ranges. Roads form a physical barrier to dispersal for many species. Agriculture and urban sprawl are also barriers to dispersal, as they are not welcoming habitats for many species.

Predict How can the effects of habitat fragmentation lead to a decrease in biodiversity?

Habitat fragmentation is a process that decreases suitable habitat. This decrease in habitat in turn leads to a decrease in carrying capacity for most species. Some species may become locally extinct, or extirpated, if a habitat patch is not large enough to support a breeding population. It also isolates smaller patches of habitat, which can prevent immigration and gene flow depending upon the degree of isolation and the species involved. For example, a small rodent would have a harder time moving to an isolated habitat patch than would a bird.

Habitat fragmentation increases the edges of a habitat, which have different biotic and abiotic characteristics than the interior. Examples of edge effects include increased predation, the development of unsuitable microclimates, and greater exposure to pollutants. Fragmentation can lead to the disruption of mating and breeding patterns or the inability to find resources necessary for survival.

Explore Online

Hands-On Activity

Modeling Habitat Fragmentation Explore how building a shopping center affects animal species within their habitat.

Cause and Effect

FIGURE 5: Monarch butterflies depend on nectar corridors during migration.

Building Wildlife Corridors

Wildlife corridors connect isolated patches of habitat. The goal of wildlife corridors is to help individuals move freely throughout their entire range. This movement helps to maintain gene flow and genetic diversity between populations of a species.

Wildlife corridors can be natural, such as riparian corridors along river systems that link populations of species that live in isolated wetlands. Wildlife corridors can also be artificial, such as the construction of highway underpasses or overpasses that let wildlife cross the roadways that fragment their habitat without danger.

Every year, monarch butterflies migrate between Canada and Mexico. These butterflies depend on nectar from wildflowers to sustain them on their long journey. Milkweed is an important food source for monarch butterfly larvae. Monarch butterflies depend on nectar corridors, which refers to a series of habitat patches that contain the plants that flower at the right times during the spring and fall monarch butterfly migration. It is particularly important that these patches be protected within urban and agricultural zones that are vulnerable to development.

Analyze What factors should be taken into consideration when making a wildlife corridor? Why is cooperation between public agencies and private landowners important when selecting the path of a wildlife corridor?

Habitat Management

Resources are often overexploited for economic reasons. In contrast, sustainable development uses natural resources in a way that meets current needs without causing permanent damage. Widespread adoption of sustainable development depends upon convincing people that nature has a cultural and aesthetic value as well as an economic one.

Protecting Habitat

Setting aside areas of public land to be preserved in a natural state is one way that governments can protect ecosystems. The Yosemite Grant of 1864 was the first federal legislation in the United States aimed at protecting nature from development. The bill designated Yosemite Valley and the Mariposa Grove of sequoia trees as protected wilderness areas. Yellowstone National Park was established as the country's first national park in 1872. The writings of naturalist John Muir were influential in convincing Americans that nature was worth protecting, in part because of its inspirational value. The next step in the preservation of U.S. public lands was the Antiquities Act of 1906, signed by President Theodore Roosevelt. It let presidents designate historic landmarks, structures, and other objects of interest as national monuments. In 1916, the National Park Service (NPS) was established with the mandate to preserve and protect natural environments for the enjoyment of future generations. One hundred years later, the NPS oversees 59 national parks and many other areas of natural and historical significance.

Today, federal conservation and management of public lands includes rangeland managed by the Bureau of Land Management, forests managed by the U.S. Forest Service, and wildlife refuges managed by the U.S. Fish and Wildlife Service. State, regional, and city governments also protect natural lands through parks and nature preserves. Many protected areas are managed with the dual purpose of human recreation and conservation of natural habitat.

FIGURE 6: President Theodore Roosevelt and naturalist John Muir advocated for the preservation of wild spaces.

Protecting Endangered Species

Both the U.S. Fish and Wildlife Service and the National Oceanic and Atmospheric Administration manage the species listed under the Endangered Species Act (ESA) of 1973. The ESA is designed to protect individual species that are near extinction by providing protection for the species and its habitat. Protection under the ESA comes in many forms including habitat conservation and captive breeding programs. The ESA recognizes the ecological, historical, educational, aesthetic, and scientific value of threatened species.

When a single species within an ecosystem is placed on a list of endangered species, other species within the ecosystem may benefit as well. For example, when the northern spotted owl was listed as threatened in 1990, logging practices in the owls' habitat were changed to leave more old-growth forest. The northern spotted owls benefited from the conservation of habitat, as did all plant, animal, fungal, and microbial organisms living in the same habitat.

Analyze Conserving habitat for which species would provide the most protection for other species in a threatened habitat: a species with a larger range over many habitats or a species with a smaller range over only the threatened habitat?

Explain How has habitat loss impacted North American prairies? How can habitat management techniques aid prairie restoration?

Introduced Species

A native species is one that lives in its historical range. Non-native species, also called introduced species, are species that have been introduced to new areas that have not historically been part of their native range. Introduced species are commonly brought to an ecosystem as a result of human activity.

Introduced and Invasive Species

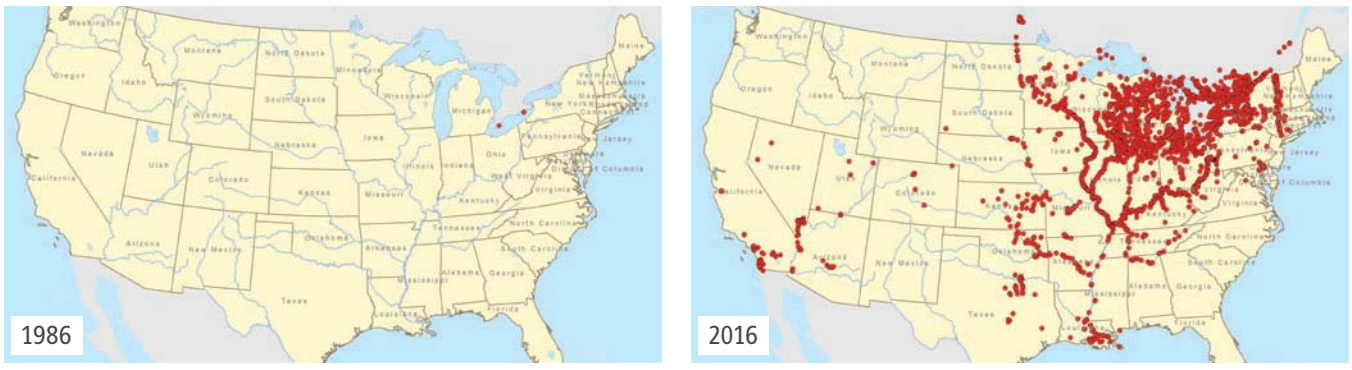
Over our history, humans have relocated many species around the world. Some introductions were accidental, such as the release of rodents into many island ecosystems from ships. Other introductions were deliberate. For example, in the late 19th century a group determined to bring every species mentioned by the English playwright William Shakespeare into the United States successfully released starlings in New York. Starlings are now found across the country and around the world.

FIGURE 7: Zebra mussels attach to mollusks and can kill them.

When an introduced species causes economic or environmental harm or poses a threat to human health, it is called an invasive species. These species typically act as predators, cause disease, or outcompete native species. Two examples of invasive species are the zebra mussel and the quagga mussel. The zebra mussel is native to Russia and the quagga mussel is native to Ukraine. It is suspected that these invasive mussels were introduced into the Great Lakes from the wastewater of transatlantic cargo ships in the 1980s. Not long after, the invasive mussels spread into nearby river drainages. Today, over 30 states have invasive mussel infestations. They compete with native mollusks for food and decrease phytoplankton and zooplankton populations in habitats they invade. They also may attach to native mollusks in numbers sufficient to kill them.

FIGURE 8: Since their introduction in the 1980s, invasive mussels have spread to over 30 U.S. states.

Explore Online



Patterns

1. What do you notice about the pattern of zebra and quagga mussel habitat expansion over time?
2. What do you think accounts for this pattern?

Engineering

FIGURE 9: Boat inspections help prevent the spread of invasive mussels.

Preventing the Spread of Invasive Mussels

Invasive mussels are notorious for attaching to and colonizing water intake pipes, buoys, fishing gear, and boat hulls. They spread naturally along waterways but can also be transported between unlinked drainages by small watercraft. Solutions such as antifouling paint prevent mussels from attaching to boats. Antifouling paints that have been successful in the past are now being phased out due to concerns about leaching metals into waterways. New, safer treatments are being developed that can be used on boat surfaces as well as engine surfaces. However, they usually are more expensive to retrofit and maintain. Boater education and mandatory boat inspections in sensitive areas also help, but invasive mussels are continuing to spread because no solution to the problem has been 100 percent effective.

Collaborate Discuss with a partner potential solutions to prevent the spread of invasive mussel species. What are some criteria and constraints that need to be considered when developing your solutions?

Invasive Species Management

Physical removal, chemical herbicides, burning, and grazing are all methods that can be used to control invasive plants. For animals, physical removal through hunting, fishing, or trapping is effective. Many successful programs for invasive species management combine several different methods.

Biological controls are a particularly useful option for invasive plants. A biological control agent is a pest or predator from the invasive species' home range. Potential biological controls must be studied extensively before they are introduced to prevent unintended impacts on the environment. For example, the cane toad was introduced in Australia to control sugar cane pests but is now itself considered an invasive species.

Invasive species have a major economical impact on humans as well as ecosystems. It is estimated that, in the United States alone, economic damage from invasive species costs more than $100 billion a year. This estimate includes money spent on prevention, early detection, control, research, and outreach activities.

FIGURE 10: Park volunteers remove invasive garlic mustard.

Analyze Introduced species contribute to the decline of native prairies. For example, non-native species may outcompete native grasses and, in some cases, degrade the quality of grazing for cattle. How could controlling introduced species help restore prairies?

Overharvesting Species

FIGURE 11: American bison were hunted to the verge of extinction in the mid-1800s.

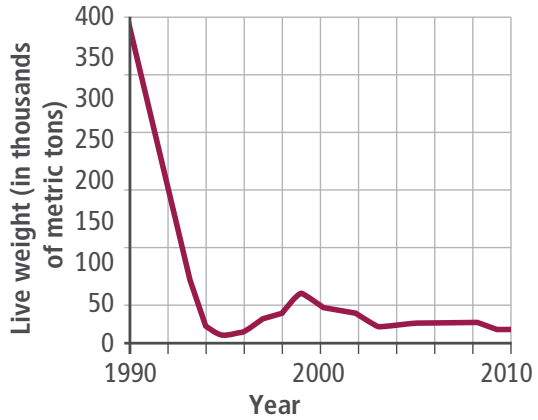
Humans use many plant and animal species for food, clothing, medicine, and other purposes. In this context, plants and animals are considered natural resources. Overharvesting occurs when individual organisms are removed from an ecosystem faster than a population can replace them. The American bison is one such example. Figure 11 shows a massive pile of American bison skulls. While Native American populations used the bison as a source of food and clothing, the arrival of the transcontinental railroad in the 1860s led to the popularization of hunting bison for sport by travelers from the East coast. The species was hunted nearly to extinction. It was only saved by the establishment of Yellowstone National Park in 1872, which was at the time home to the last surviving herd of bison.

Overfishing

Fishing is defined as the harvesting of aquatic species. Fisheries can be overharvested if more individuals are removed than the population can produce. In other words, the reproduction rates of a fishery must be equal to or higher than the harvesting rates, or overharvesting will occur. Overharvesting can cause the collapse of a fishery if it is widespread and populations are harvested to the point of extremely low numbers, particularly in terms of females. If fisheries continue to be harvested after a collapse, the harvested species could become extinct. Aquatic species that have been overharvested include swordfish, Atlantic cod, and tuna. Oceanic fisheries are particularly vulnerable to overharvesting because no single nation owns the open oceans. In order to maintain sustainable fisheries, countries must cooperate together to ensure that populations are not overharvested.

Data Analysis

FIGURE 12: North Atlantic Cod Fishery Collapse



Source: Department of Fisheries and Oceans, Canada

North Atlantic Cod Fishery Collapse

The Grand Banks cod fishery, located off the coast of Newfoundland, was managed starting in the 1950s in an effort to preserve the fishery and let cod populations rebound. Instead of rebounding, cod populations continued to decline through the 1970s. New fishing technology in the 1980s along with the lack of suitable fishing regulations led to the collapse of the fishery in the early 1990s. Cod fishing was banned in the Grand Banks in 1992. There were very few cod fish left capable of reproducing at the time of the fishery collapse, and the fishery has yet to recover.

1. What has been the largest annual catch since the fishery collapsed in the early 1990s?
2. What factors may be hindering the recovery of the fishery?
3. Why are no-fishing zones important to the recovery of a fishery?

Overhunting

Hunting, trapping, and collecting can be used to manage a population of animals. However, if more individuals are continually removed from a population than can be replaced by normal population growth, the population will decline and eventually become extinct. Overhunting impacts biodiversity in two ways. If extinction or extirpation occurs, species richness—the number of species present in a given area—will decrease. Reducing the population of any species to very small numbers reduces genetic diversity of that species and may cause a genetic bottleneck. Species richness and genetic diversity are measurements of biodiversity. Decreases in these two values will lead to a decrease in biodiversity.

FIGURE 13: The western black rhinoceros was declared extinct in 2011.

The western black rhinoceros, shown in Figure 13, was one of four subspecies of black rhinoceroses that once ranged across central and western Africa. Three factors led to the demise of this subspecies. First, sports hunting decimated many populations in the early 20th century. Second, the clearing of land for agriculture destroyed rhinoceros habitat. Third, the rise in popularity of traditional Chinese medicine in the 1950s, in which powdered rhinoceros horn plays a major part, led to a massive increase in poaching. By the early 1990s, less than 2 percent of the original population of black rhinoceroses were left in the wild. The last remaining western black rhinoceroses—just five of them—were observed in 2001. A decade later, with no further observations, the International Union for Conservation of Nature formally declared the western black rhinoceros extinct.

Sustainable Fishing and Hunting Practices

Humans have found solutions to overharvesting, such as sustainable fishing practices. Many fisheries now have regulations for catch size, season length, and the type of equipment that can be used for fishing. These regulations aim to keep fish populations at sustainable levels while also providing the food source that humans depend upon. Regulations also help reduce bycatch, which refers to any species captured during commercial fishing that is not the target species. Bycatch is a threat to many vulnerable species such as sea turtles and dolphins. For example, fine-meshed nets used for catching shrimp now must be equipped with turtle excluder devices. The devices prevent turtles and other large species from becoming trapped in the nets.

Explain How can regulating catch size, equipment used, and season length protect aquatic biodiversity?

Hunting in a sustainable manner conserves populations and prevents overharvesting. Similar to fishing, wildlife managers regulate hunting seasons, the age and sex of animals that can be harvested, and the equipment that can be used.

Analyze What resources might have been overexploited as part of the destruction of North American prairies?

Language Arts Connection

Rethinking the Value of Non-native Species

There is a distinct bias against non-native species in both science and public communities. In some ways, this means scientists have effectively educated the public about the dangers of invasive species.

This distrust of non-native species seems to be well-founded. Land and water managers dealing with kudzu or zebra mussel infestations can give first-hand accounts about how destructive invasive species can be. Many scientists think that it is both fair and necessary to be critical of non-native species given the amount of damage they can cause. Invasive non-native species take over landscapes and often outcompete other species for precious resources.

The harm caused by invasive species is not always immediate. A wait-and-see approach will not always work, as a once-harmless species can quickly turn into an invasive nightmare. For example, the Brazilian pepper-tree was introduced to the U.S. as an ornamental plant and originally did not seem to be invasive. Today, it is an invasive threat to mangrove communities in Florida.

However, some scientists have begun to challenge the "native or bust" ideals that dominate current science. They quickly point out that some non-native species provide important ecosystem services, such as pollination of native flowers and soil stabilization. For example, honey bees are not native to North America.

FIGURE 14: Though not native to North America, honey bees are integral pollinators.

They were introduced by early European settlers in 1622. However, today they are invaluable pollinators of crops and producers of honey.

Non-native plants often provide habitat for native species. Salt cedar, introduced to control erosion, is particularly invasive in the southwestern United States, but has become a critical nesting habitat for the endangered southwestern willow flycatcher. An attempt to remove salt cedar populations was accompanied by a decline in the flycatcher population.

Other issues to consider in the debate of whether non-native species should be welcomed into new ecosystems are how the term *native* is defined and what should happen to non-native species that are now threatened in their home ranges. *Native* defines a species' home range during a certain period of time. Most species were non-native at some point, meaning they arrived in their current home ranges from elsewhere.

Further confusing the difference between native and non-native species is that climate change is causing species to move into new ranges on their own. Cold-adapted species are moving to higher elevations or toward the poles in pursuit of suitable temperature ranges. Warm-adapted species are expanding their ranges as they move into previously unsuitable habitat. Climate change, habitat loss, and other human impacts can mean that a non-native species may be threatened in its home range. Should these species be removed from their new ranges even if they may not survive in their home ranges?

Both sides of the debate want to maintain biodiversity and ecosystem function. The difference is how non-native species fit into the picture: as potential beneficial contributors or as a potential destructive force.

Language Arts Connection
Write a short position paper focused on whether all non-native species should be targeted for removal from new environments. Support your position and claims with evidence from the passage. You and your classmates will discuss your positions in a classroom debate.

DESIGN A PRESERVE IN YOUR COMMUNITY | PROTECTING BIODIVERSITY | KILLER KITTIES | Go online to choose one of these other paths.

Lesson Self-Check

CAN YOU EXPLAIN IT?

FIGURE 15: Land managers use prescribed burns to maintain prairie ecosystems.

Fire plays an important role in healthy prairie ecosystems. Prairies, especially those with tall-grass species, accumulate dead biomass year after year as grasses go dormant in the wintertime and new vegetation emerges in the springtime. Historically, fire was a frequent disturbance regime that removed this layer of dead plant material. The burning of biomass immediately makes the mineral nutrients in the biomass available to the new growth as ash. With the dead biomass gone, new vegetation not only has more nutrients, it also receives more sunlight. This improves growth in the seasons that follow fires. Fire increases biodiversity by opening new habitat and increasing the establishment success of pioneer species.

Explain Refer to the notes in your Evidence Notebook to answer the following questions:

1. How does burning a prairie increase biodiversity?
2. Why is maintaining biodiversity important?

Biodiversity is declining as humans change habitats, introduce invasive species, and overharvest native species. Humans will continue to cause significant impacts to the environment for the foreseeable future. The implementation of sustainable development practices will be key to managing resources for both current and future generations. More progress is needed in this area in order for natural spaces and biodiversity to be preserved and protected while also providing enough resources for Earth's growing human population.

CHECKPOINTS

Check Your Understanding

1. Make a diagram that models how crowding in a fragmented habitat acts as a negative feedback on the system. What is the effect on population size and carrying capacity?

2. Rodent species were introduced to many island systems accidentally as ships traveled around the world. Introduced rodents are the likely culprits in at least 13 extinctions of native species. Many rodents will opportunistically feed on bird and turtle eggs, small birds, reptiles, and many other native species. What might happen to the island system if a rodent species is introduced that has no competitors for its preferred niche, no predators, and no disease or parasites?

3. Why is monitoring an important part of controlling invasive species?

- **a.** Monitoring can prevent the spread of invasive species.
- **b.** Monitoring can identify new populations of invasive species while they are still small.
- **c.** Monitoring can maintain the historic state of a landscape.
- **d.** Monitoring can assess the impacts an introduced species could have on a new environment.

4. Why are species with low reproductive rates more sensitive to extinction due to overexploitation than those with higher reproductive rates?

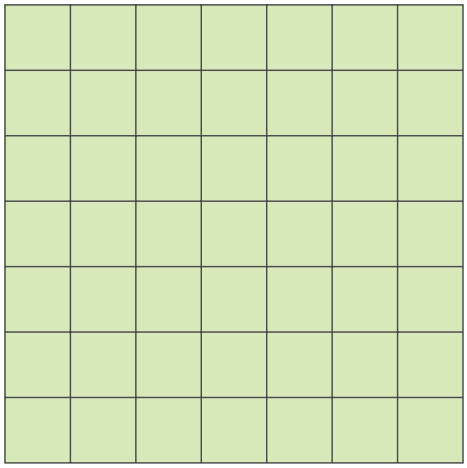
5. Use the terms below to complete the paragraph.
decreases, directly related, increases, inversely related

In general, the level of biodiversity in an ecosystem is _____ to the amount of habitat loss. When the amount of habitat loss increases, the degree of biodiversity _____. Habitat connectivity is _____ to genetic diversity in a population. When habitat connectivity increases in a fragmented landscape, genetic diversity _____.

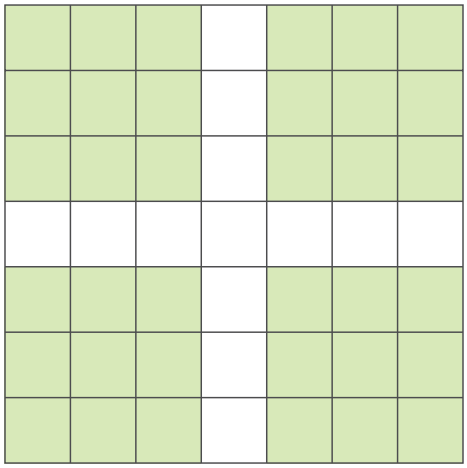
6. Choose a species endangered by habitat loss or overharvesting. Then make a model that shows how technology has increased or facilitated the habitat loss or exploitation affecting the species.

Use Figure 16 to answer Questions 7–10.

FIGURE 16: Habitat Fragmentation



a Original habitat



b Fragmented habitat

7. Species A was separated into equal populations when the fragmentation occurred. However, this species does not live within 1 km of a forest edge (1 square = 1 km). How much suitable habitat did Species A have in the original habitat, and how much suitable habitat does Species A have in the fragmented habitat?

- **a.** 25 km^2, 4 km^2
- **b.** 25 km, 16 km
- **c.** 9 km^2, 1 km^2
- **d.** 3.5 km, 1.5 km

8. Analyze the habitat models and calculate the following values for each habitat:
   a. total area (km^2)
   b. total length of edge (km)

9. What would have to happen to the fragmented habitat for Species A to become locally extinct in this area if all other features of the system remain unchanged?

10. How much has edge habitat increased in the fragmented habitat? How much has suitable interior habitat declined in the fragmented habitat?

11. Which of the following is an example of a barrier in a fragmented habitat? Select all correct answers.
   a. road or pipeline
   b. permanent structure that keeps habitat patches from being rejoined
   c. piece of land that connects habitat patches
   d. something the prevents a species from accessing its entire home range

12. Phytoplankton are primary producers at the foundation of many food webs. Why should species like phytoplankton be of concern for scientists during a large extinction event like the one Earth is currently experiencing?

13. Why is protecting an entire ecosystem preferable over protecting a single species? Explain.

14. Use your knowledge of ecosystem stability to explain why it is important to maintain biodiversity.

15. In what ways can an introduced species impact an ecosystem it has colonized? Use a specific example in your answer.

MAKE YOUR OWN STUDY GUIDE

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

Human activities can have a negative impact on biodiversity.

As a global society, humans need to find a way to balance the economic benefits of development with the cultural and environmental benefits of biodiversity.

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 human impacts are changing the stability of ecosystems. Think about specific causes and effects related to declining biodiversity that could be linked to human activities.