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Biodiversity Case Studies

Students analyze case studies in natural systems to illustrate the complexities of biodiversity.

SECTION 2
Natural Systems

Subjects:
science, biology, sociology, mathematics, reading

Approximate lesson time:
2 hours

Materials:
copies of case studies, paper and pencil

STUDENT OBJECTIVES:

At the end of this lesson, students will be able to:

1. Define *biodiversity* and provide real-world examples.
2. Outline changes that took place in an ecosystem when populations of a species fluctuated.
3. Assess the role humans have taken in altering biodiversity intentionally or nonintentionally.
4. Evaluate the importance of biodiversity from differing perspectives.

VOCABULARY:

biodiversity • predator • prey • carnivore • omnivore • scavenger • producer • consumer • decomposer • ecosystem • natural system

TEACHER BACKGROUND:

This activity gives students real-life scenarios showing the importance of biodiversity in natural ecosystems. For example, a native prairie with 200 species of grasses and forbs (wildflowers) is a diverse ecosystem; a cornfield with one species (corn) and a half dozen weeds is not a diverse ecosystem. More animals will live in a wild native prairie than in a cornfield because a wider variety of food and shelter is available to suit the animals.

What is biodiversity?

The term *biodiversity* is short for biological diversity. This topic examines all living organisms, species and populations on earth. It also includes the genetic variation among categories, and all their biological communities and ecosystems. It also refers to the interconnectedness of genes, species and ecosystems and their interactions with the environment. Usually, scientists refer to three levels of biodiversity: genetic, species and ecosystem diversity. In this lesson we explore species and ecosystem diversity.

Species diversity is all the differences within and between populations of species. Ecosystem diversity is all the different habitats and biological communities on the earth and the variations among them.

What threatens biodiversity?

Species are becoming extinct at the fastest rate known in geological history, and most of these extinctions have been tied to human activity. Habitat loss due to human activity and population growth is a major cause of the loss of species and ecosystems. Alterations of

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National Science Education Standards

Unifying Concepts and Processes

Systems, order, and organization

Evidence, models, and explanation

Change, constancy, and measurement

Evolution and equilibrium

Science as Inquiry

Abilities necessary to do scientific inquiry

Understanding about scientific inquiry

Life Science (5–8)

Structure and function in living systems

Reproduction and heredity

Regulation and behavior

Population and ecosystems

Diversity and adaptations of organisms

For more correlations, please see Appendix IV.

ecosystems, introduction of non-native species and overhunting can also lead to a loss of biodiversity.

Why is biodiversity important?

The Ecological Society of America is an organization dedicated to preserving biodiversity. They state the following:

Diversity breeds diversity. A diverse array of living organisms allows other organisms to take advantage of the resources provided. For example, trees provide habitat and nutrients for birds, insects, other plants and animals, fungi, and microbes.

The diversity of life is not only important biologically, but it also enriches the quality of our lives in ways that are not easy to quantify. Humans have always depended on the Earth's biodiversity for food, shelter, and health. But many people also believe that biodiversity is intrinsically valuable and is important for our emotional, psychological, and spiritual well-being.

Biodiversity also supplies indirect services to humans that are often taken for granted. These include drinkable water, clean air, and fertile soils. The loss of populations, species, or groups of species from an ecosystem can upset its normal function and disrupt these ecological services. Recent declines in honeybee populations may result in a loss of pollination services for fruit crops and flowers.

The Earth's biodiversity contributes to the productivity of natural and agricultural systems. Insects, bats, birds, and other animals serve as pollinators. Parasites and predators can act as natural pest controls. Various organisms are responsible for recycling organic materials and maintaining the productivity of soil.

Ecologists conduct research to better understand biodiversity, quantify its loss, and develop strategies for conserving and using it. Much is still unknown about what species exist and where, and the relationships among them. By inventorying and monitoring biodiversity, ecologists study species abundance, functions, interactions, and importance to maintaining or enhancing the quality of human life.

Information taken from

http://esa.sdsc.edu/biodiv2.htm, the Ecological Society of America, 1707 H St., NW, Suite 400, Washington, DC 20006, Tel:202-833-8773.

ACTIVITIES:

A. Share the story below to arouse students' curiosity.

CRISIS ON THE KAIBAB

The Kaibab Plateau is a semi-arid region located near the north rim of the Grand Canyon. In 1906, mule deer, mountain lions, wolves and coyotes lived there in a naturally functioning ecosystem. Also living there were about 200,000 sheep. That year, President Theodore Roosevelt declared the Kaibab Forest a national game reserve, so bounty hunters removed all the predators to prevent their reducing the mule deer population. Most of the sheep were moved elsewhere so the mule deer could feed on the grasses and shrubs without competition.

Without predation and competition, the mule deer population exploded, growing from 4,000 in 1906 to more than 100,000 around 1924. The deer ate every blade of grass, leaf, and shrub in sight.

In the late 1920s an estimated 60,000 mule deer starved to death during the winter or died of disease. The deer population continued to decline until the early 1940s when the population returned to levels near that of 1906.

B. Ask students:
- What caused the mule deer population to increase?
- Why did it eventually decrease?

C. Depending on the age level of students, review some of the basic ecological principles of food chains and nutrient recycling. Review or brainstorm what types of organisms make up producers, consumers and decomposers. A quick overview of carnivores, herbivores, omnivores, scavengers and predator-prey relationships may also be helpful.

D. Case Studies
1. Divide students into small groups.
2. Define the term *biodiversity.* This is a large and complex concept for students to grasp. Try describing biodiversity in terms of organisms found in your local or regional area to provide students with something concrete and familiar. For example, describe biodiversity in an organic garden or lack of biodiversity (in terms of grass species) on a golf course.
3. Assign each group a "biodiversity case study."
4. Students will read the case study and examine the complexity of species interaction and biodiversity using the following suggestions:
- Discuss what happens when one species suddenly increases or decreases in number. What is the effect on other species in the ecosystem?
- What kinds of actions did wildlife managers take to initiate changes?
- Evaluate the importance of biodiversity from different perspectives: a species with declining numbers, a species with increasing numbers, an exotic (non-native) species, an ecologist, a developer.
- Diagram the changes or interactions among the species outlined in the case study, or perform a play.

ASSESSMENT:

A. Have each group give a short presentation about the case study examined. Encourage students to be creative!

Ideas for writing assignments

What kinds of natural events could affect biodiversity in the short term and long term (e.g., hurricanes, floods, mudslides, earthquakes, volcanic explosions and meteor collisions)?

Discuss how human habitation has altered wildlife populations over time. What has caused the enormous changes in biodiversity in the past 500 years? What is the

> *We consider species to be like a brick in the foundation of a building. You can probably lose one or two or a dozen bricks and still have a standing house. But by the time you've lost 20 percent of species, you're going to destabilize the entire structure. That's the way ecosystems work.*
>
> *Donald Falk,* Christian Science Monitor, *26 May 1989*

correlation between human lifestyle, use of resources, habitat destruction and loss of biodiversity?

Compare and contrast the need for biodiversity from different perspectives: a family of 15 living in poverty using slash-and-burn farming methods in the Brazilian rain forest versus a vegetarian college student from a middle-class family.

Brainstorm three reasons why diversity is disappearing in our ecosystems. What actions can students take that may affect biodiversity in their local area?

How has the role of humans in the development of transportation over the centuries affected biodiversity? For example, look at changes in biodiversity on Hawaii, Australia and Madagascar, and the spread of exotics and non-native species.

Imagine Ebola or a related virus has gone airborne and caused a global epidemic. Ninety percent of humans on the planet perish. What kind of effect would this have on biodiversity? Paint a picture of how the world would look 100 years after the event.

How has global climate change affected biodiversity in the past? Hypothesize on the effects of global warming in the near future. How might biodiversity and the location of ecological zones be altered?

EXTENSIONS:

1. Instruct students to find other wildlife case studies from your state wildlife agency.

What do these case studies say about the effects of biodiversity on animal populations and ecosystems?

Do animal populations always follow the patterns we expect them to follow? Why or why not?

What can the trends we see in these wildlife case studies teach us about how we should manage our wildlife populations?

2. Defend or refute the idea of introducing wolves or grizzlies in the West based on information learned from these case studies.

BIODIVERSITY CASE STUDY

Starfish Rule the (Tide)pool

Researchers are finding that not all species are equal in their effect on an ecosystem. Top predators can sometimes have an especially powerful impact on a habitat. One of the first researchers to demonstrate this principle was Robert Paine from the University of Washington. In a 1966 study, Paine removed a starfish *(Piaster ochracues)* from an experimental area in the intertidal (or tidepool) regions of the Pacific seashore. Intertidal areas are the areas between the high and low tide marks on the shore. They are underwater during high tide and open to the air during low tide.

When Paine removed the predatory starfish, the barnacles and mussels that starfish fed on increased in number and outcompeted other, more slow-growing or slow-reproducing species. It appears that the starfish, by feeding on barnacles and mussels, clears out portions of the intertidal area. This disruption provides space for other species. The number of species in each study area dropped by almost half, from 15 species to 8.

Paine studied the effect of removing other predators from his enclosures, but none of those removals had results comparable to the starfish removal. In fact, the removal of the starfish affected the varieties and population densities of all other species in the area, even species that starfish did not prey upon. The starfish seems to govern the biological diversity of the entire ecosystem.

Paine is quick to point out that the reason he terms starfish a predatory "keystone species" is because its impact on the ecosystem is much greater than its size would suggest. Obviously large kelp, old-growth trees and huge expanses of prairie grass have a large impact on a habitat and the species that live there, but that impact is equal to these plants' relative biomass. For that reason, he would not consider them "keystone species."

Sources:

Mills, L. Scott, Michael E. Soulé, and Daniel F. Doak. 1993. The keystone-species concept in ecology and conservation. BioScience *43, 4: 219.*

Paine, R. T. 1966. Food web complexity and species diversity. American Naturalist *100: 65–75.*

Paine, R. T. 1980. Food webs: Linkage, interaction strength and community infrastructure. Journal of Animal Ecology *49: 667–85.*

BIODIVERSITY CASE STUDY

Coyotes in Southern California

In 1999, two researchers (K. R.Crooks and M. E. Soulé) determined that large predators like coyotes have a major impact on the diversity and population numbers of songbirds in patches of sage-scrub habitat in southern California. Larger natural areas that had coyotes had more songbirds and more diversity of bird species.

Coyotes had this impact by preying upon "mesopredators" (medium-sized predators) like domestic cats, striped skunks, raccoons, gray foxes and opossums. In the absence of coyotes, the mesopredators increased in abundance and fed heavily on the birds. That increased predation led to a drop in native bird populations, often to the point where local extinctions occurred or were inevitable. Thus, the fate of the birds is driven largely by the survival of a predator two trophic (food web) levels above it. If the factors that limit a mesopredator population disappear, that population may experience what is called ecological release, reproducing quickly and expanding their population.

Crooks and Soulé discovered that larger patches of wild land have a positive effect on coyote and bird populations. Cats become dinner more often in larger wild areas that are home to coyotes. Coyotes have a negative effect on mesopredators (more coyotes = fewer cats).

Mesopredators (such as cats) have a negative effect on birds, which means that the presence of cats causes bird numbers to decline. Cats predate heavily on bird populations because they are recreational hunters. Human owners feed cats and then let them hunt in nearby wild areas, permitting many more predators to exist in the ecosystem than the carrying capacity the scrublands can support. A scrubland habitat patch of about 20 hectares could easily have 35 cats from surrounding housing developments. By comparison, the same property could naturally support only one or two pairs of native foxes, a natural mesopredator.

The longer that a wild area has been isolated from other wild areas by suburban development, the worse the decline of bird populations. These factors combine to spell doom for native scrubland birds such as Western Scrub-Jays, California Gnatcatchers, California Quail, Bewick's Wrens and Wrentits in small, isolated scrublands that have high numbers of cats and other mesopredators.

The presence of coyotes seems to keep mesopredators out of wild areas. Perhaps cats instinctively avoid areas where they are not the top predator. Coyotes also kill and eat mesopredators. In the Crooks and Soulé study, about 21 percent of coyote scats contained cat remains, and coyotes killed 25 percent of radio-collared cats.

Sources:

Crooks, K. R., and M. E. Soulé. 1999. Mesopredator release and avifaunal extinctions in a fragmented system. Nature *400: 563–66.*

Krebs, C. J. 1994. Ecology: The Experimental Analysis of Distribution and Abundance. *4th ed. Menlo Park, CA: Addison-Wesley.*

Saether, B.-E. 1999. Top dogs maintain diversity. Nature *400: 510–11.*

Schmidt, K. A. 2003. Mesopredator effects on songbirds. Conservation Biology *17, 4: 1141–50.*

BIODIVERSITY CASE STUDY

Lyme Disease Outbreak

Maintaining ecosystem health may improve human health as well. In the northeastern United States, the outbreak of Lyme disease has led researchers to conclude that forest fragmentation and the loss of predators for white-footed mice and white-tailed deer (the main carriers of the disease and the ticks who transmit it) have resulted in population explosions for deer, mice and deer ticks. As humans are increasingly suburbanizing forest areas and coming in close contact with both deer and mice, they are much more likely to be bitten by infected deer ticks and to contract the disease.

Lyme disease was named in 1977 when doctors identified an arthritis-like condition in children near Lyme, Connecticut. Since that time the disease has spread to the Midwest. Lyme disease is caused by spirochete *(Borrelia burgdorferi)*, a bacterium transmitted to humans by the bite of infected ticks. Typical symptoms include fever, headache, fatigue and a characteristic skin rash.

It seems likely that Lyme disease has persisted for a long period of time in wildlife populations, but because of natural predator and forest habitat population controls, deer and mice populations did not come in such close proximity to human communities. The population density of white-footed deer mice and deer is high in forest fragments, where predator populations in general are reduced by humans. Lyme disease risk is 10 times greater in small forest fragments than larger fragments. Small forest fragments near human dwellings and activity carry the highest densities of mice, deer and infected ticks.

Over the past 50 years, the human population and suburban development in the highly populated northeastern states have moved humans in much closer proximity to deer and mouse populations while at the same time fragmenting second-growth forests in the region. Since deer and mice thrive on forest edges and many deer and mouse predators (wolves, owls, weasels, foxes) survive better in large forested regions, humans may have created the perfect conditions for an outbreak of Lyme disease.

Sources:

Koren, H. S., and D. Crawford-Brown. 2004. A framework for the integration of ecosystem and human health in public policy: Two case studies with infectious agents. Environmental Research *95: 92–105.*

Ostfeld, R. S., C. G. Jones, and J. O. Wolff. 1996. Of mice and mast. BioScience *46: 323–30.*

Ostfeld, R. S., and F. Keesing. 2000. Biodiversity and disease risk: The case of Lyme disease. Conservation Biology *14: 722–28.*

BIODIVERSITY CASE STUDY

There "Otter" Be Kelp Forests

Where we have sea otters, we have ocean kelp forests. Kelp is a long, algal organism that lives in near-shore ocean, growing up to 165 feet tall. Many other species live in the thick kelp areas, called "forests," comparable to life in a coral reef.

When the sea otters disappear, due to trapping, disease or killer whale predation, kelp forests shrink or disappear. This seems to happen because sea otters eat sea urchins, aquatic organisms related to starfish that look like small, spiky purple hedgehogs. Without predation by otters, sea urchins will eat the kelp until it is gone, creating an "urchin barrens" on the sea floor.

Unfortunately, when the yellow-brown rubbery kelp disappear, other organisms are also affected. Kelp provide shelter for spawning herring and habitat for many other organisms and increase water clarity and color.

When biologists release new sea otters into areas where they had been extirpated, they immediately begin feeding on sea urchins, and the kelp forests begin growing back. In a study in Alaska, researchers determined that the sea urchin population declined by 50 percent in the Aleutian Islands and by nearly 100 percent in southeast Alaska after sea otters moved in to previously unoccupied habitats. In some areas, kelp grew dramatically when the otters returned.

Because of the direct relationship that seems to exist between sea otters and the kelp forest ecosystem, researchers term the sea otter a "keystone species," meaning that it is a species that is critical to ecosystem to survival.

Source:

Estes, James A., and David O. Duggins. 1995. Sea otters and kelp forests in Alaska: Generality and variation in a community ecological paradigm. Ecological Monographs *65, 1: 75–100.*

BIODIVERSITY CASE STUDY

Yellowstone National Park

The return of the gray wolf to Yellowstone National Park has caused a cascade of effects that scientists are only beginning to understand. Wolves were exterminated from the park by the early 1930s because they were believed to be a threat to humans and a menace to the ecosystem. Sentiments changed, and in 1995 and 1996 wolves were reintroduced into Yellowstone as well as central Idaho.

In the time since the wolf's return to Yellowstone, biologists have been monitoring the plants' and animals' response to wolves. Preliminary results from scientific studies reveal that changes are occurring. One study showed that elk—the wolf's primary prey—changed their browsing behavior after wolves were reintroduced to the park. Prior to the return of wolves, high numbers of elk grazed heavily on trees and other plants in the river valleys. With wolves present, the elk must now be more vigilant to avoid predation by wolves. When elk move about the ecosystem more actively, the trees in the river valleys are not grazed as heavily and can regenerate more readily. Scientists have noted that aspen, willow and cottonwood trees all are growing taller and spreading more widely in these areas. With more hardwood trees available, beavers have more food and build dams that create ponds. With expanded riparian areas, a wider range of plants and animals find homes, including songbirds and trout.

Other changes are being observed as well. When wolves kill elk, they often leave food behind for scavengers such as ravens, grizzly bears, magpies, wolverines, eagles and various beetle species, helping those populations to grow strong. Wolves reduce coyote numbers because the two species compete for food. Fewer coyotes mean that red foxes, hawks and eagles have less competition for smaller prey such as ground squirrels and gophers.

Ecological relationships are complex and difficult to document. While many changes in Yellowstone's ecosystem have been documented since wolves arrived, it is impossible—and inappropriate—to attribute all the changes to wolves. Drought, extreme winter weather and even human activity affect the ecosystem. Even if biologists could document all the aspects of such complex cause-and-effect interactions, the story is still unfolding. All the animals and plants in the Yellowstone ecosystem will continue to change and adapt in response to many factors, including each other, for many years to come. Fifty or 100 years from now we may begin to have a clearer picture of the true impact of the wolf's reintroduction to Yellowstone.

Sources:

Ripple, W. J., and R. L. Beschta. 2003. Wolf reintroduction, predation risk, and cottonwood recovery in Yellowstone National Park. Forest Ecology and Management *184: 299–313.*

Smith, D. W., R. O. Peterson, and D. B. Houston. 2003. Yellowstone After Wolves. BioScience *53:330–40.*