**Bioprospecting: Investigating the Costs**

**And Benefits of Scientific Research**

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**Lesson Description**

This lesson is designed so that students will better understand the decision-making process when dealing with natural resources within Yellowstone National Park. The issue of land use for biological research will be explored, specifically the mining of natural resources within geothermal areas for the purpose of studying extremophiles. The practice known as bioprospecting involves searching for genetic and biochemical resources for research purposes, some of which has become quite profitable. In 1985, an enzyme from the microorganism *Thermusaquaticus*was found useful in producing quick copies of DNA that could be used in genetic engineering. The company, who patented the enzyme, received hundreds of millions of dollars and the scientific community has been forever changed. There are now a host of different applications originating from microbes within the Park, from improving detergents to improving yields in the food supply. Researchers are granted permits to do research within the Park and agreements must be reached as far as sharing any benefits from that research are concerned. Some fear that the increased use of the park for biological research will adversely affect the park and lead to a more relaxed role on conservation. It is important for students to understand how the benefits of bioprospecting and the potential negative environmental impacts should be considered in the decision-making process.

Students will participate in activities that will help them to see the effects that bioprospecting has on society. Using their knowledge taken from scientific research on the microorganisms within the park, they will investigate and debate on possible alternatives tobioprospecting. The economic concepts of property rights, trade-offs, and “tragedy of the commons” will be integrated within the lessons to aid students in developing their own stance on the issue. Researching various resources and debating the issue form the critical thinking skills for this lesson.

**Introduction**

This lesson deals with land use within Yellowstone as it relates to scientific research ventures and the cost and benefits associated with it. Bioprospecting has the potential to positively impact the health of the planet by creating solutions to problems that we currently face. When research leads to commercially-viable products, the parks get a share of the profits through benefit-sharing agreements. This agreement has helped ensure that highly profitable research originating within the Park doesn’t slip out of their hands, like the PCR technique did in the ‘80’s. The enzyme responsible for the process which was gathered in the Park still yields approximately 100 million dollars per year. Another fear associated with bioprospecting is that the ecosystem where the thermophiles exist may be harmed in some way due to the amount of samples taken and/or the ability of the ecosystem to withstand the researcher’s actions. The discoveries made at the Park are also subject to criticism from those who feel that tampering with the ecosystem’s unique inhabitants may lead to unforeseen dangers with regards to genetically modified organisms. This lesson will provide students with the opportunity to analyze the information and how it relates to their values. Using critical thinking skills, students will be better able to make decisions about the costs and benefits of bioprospecting.

**Concepts**

* Tragedy of the Commons
* Cost-Benefit Analysis
* Benefit Sharing
* Ecosystems
* Biochemistry

**Indiana Standards (Science, Economics, and Government)**

**Life Science**

B.1.28 Genetic Variation

B.1.29 Continuity of Life

B.1.31 Survival of the Fittest

B.1.34 Evolution of a Species

B.1.37 Health of Ecosystems

**Economics**

E.1.2 Scarcity, opportunity costs and tradeoffs

E.1.4 Positive and negative incentives

E.1.7 Property rights (Government)

E.3.3 Economic institutions evolve in market systems (Government)

**Government**

USG.5.7 Important citizen actions that monitor and influence government

USG.5.12 Use information from a variety of resources

**Objectives**

* Identify bioprospecting as a key issue within Yellowstone National Park
* Understand the concept of “tragedy of the commons” and identify problems with land use
* Think critically about positions given their differences of opinion on environmental and economic issues
* Understand important economic concepts such as cost-benefit analysis, trade-offs, and benefit sharing

**Daily Lesson Plans**

**Day 1**

1. Begin the day with an the introduction to the Yellowstone experience by viewing the PowerPoint presentation.
2. Complete an activity on the “Tragedy of the Commons” by explaining the history behind the concept.
3. Students will work in groups of fours. They may catch as many gold fish crackers from a group of 16. The number of gold fish doubles each round and the students record this information in a table (See attached). The selection process should not allow students to talk and lasts for five rounds.
4. Students are to answer questions one and two in the discussion questions (See attached). While students are still silent, continue the game and have students now collect data in the Second game table.
5. They will then answer the rest of the discussion questions to develop a way to solve the problem.

**Day 2/3**

1. Students will discuss a case study involving water pollution and decide on the best decision to make determine what the goals are and possible alternative. The lesson is Activity 9, from the Water Resources lesson in *Energy, Economics and the Environment* by the National Council on Economic Education.
2. After the final decisions are presented, students will move into three separate groups. Each group will take a look at one side of the issue on bioprospecting in Yellowstone National Park. Students will read print outs of information on thermophiles and the issues. They will be able to access computers to search for new material that may prove useful.
3. Allow access to geothermal features in the Park with a benefit-sharing plan
4. Restricting access to geothermal areas of the Park except to biological researchers
5. Allow access to geothermal features in the Park, except those that threaten biodiversity

**Day 4**

Students debate the costs and benefits of each position. Each group will be allowed five minutes to make their statements. Students will be allowed to respond with their responses lasting no more than two minutes. At the end of the debate, questions may be asked and the class will vote on the most authentic experience. The winning team will get 5 bonus points.

The rubric used in grading each group:

Organization \_\_\_\_\_\_\_\_\_\_\_\_ /10

Information \_\_\_\_\_\_\_\_\_\_\_\_ /10

Persuasiveness \_\_\_\_\_\_\_\_\_\_\_\_ /10

Presence \_\_\_\_\_\_\_\_\_\_\_\_ /5

Total \_\_\_\_\_\_\_\_\_\_\_\_ /35

**Student Data Tables**

**FISH DATA TABLE**

**1st Game**

**Commons Lake**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Number of fish in the lake (after reproduction)** | **Number of fish caught per person** | **Number of fish caught per year (by everyone)** |
| **Year One** |  |  |  |
| **Year Two** |  |  |  |
| **Year Three** |  |  |  |
| **Year Four** |  |  |  |
| **Year Five** |  |  |  |
| **Total** |  |  |  |

**2nd Game**

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Number of fish in the lake (after reproduction)** | **Number of fish caught per person** | **Number of fish caught per year (by everyone)** |
| **Year One** |  |  |  |
| **Year Two** |  |  |  |
| **Year Three** |  |  |  |
| **Year Four** |  |  |  |
| **Year Five** |  |  |  |
| **Total** |  |  |  |

**Tragedy of the Commons**

**Discussion Questions**

1.       Did anyone in your group take too many fish?  Did everyone try to take as many as possible?  Why or Why not?  Does society reward those with the “most”?

2.       Did anyone sacrifice the # of fish they caught for the good of the community?  Why or why not?  Does society ever reward that type of person?

 3.       In Game two... **how** did your strategy change, if at all?  Does it make a difference to know what the rewards are?

4.   Is it possible to maximize the number of fish caught/person **AND** the number of fish remaining in the pond **at the same time**? Why or Why not?

5.   Think of a **local commons** that you are familiar with. [parking lots, dorm social rooms, bathrooms, bookstalls, etc.] Do similar situations arise? Explain.

6.   What are some **natural resources** that are **common** resources?

7.       What are the **global commons**?  Are these being used wisely?  Why or why not?

8.   What can people do to use these resources most wisely?

Script for PowerPoint

**Bioprospecting: Investigating the Costs and Benefits of Scientific Research**

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1. Yellowstone National Park
   1. Is named after the major river that flows through it, the Yellowstone River.
   2. Is 3,472 sq. miles of area (2.2 million acres)
   3. Stretches over Montana, Idaho, and Wyoming
   4. Sits atop an active volcano
   5. Received 3.3 million visitors last year (Current record)

*An overview of the park is discussed. Key features of the park are a result of the large volcano and time. The amount of visitors to the park remains large, but so is the area open to the public. As we move through these slides, keep in mind that the volcano continues to influence what goes on in the park.*

1. The Yellowstone River
   1. Carved the Grand Canyon of Yellowstone after buried by caldera (type of volcano)
   2. Flows into Yellowstone Lake, large basin formed by eruptions 640,000 years ago
   3. Under the influence of glacial advancement and retreat which occurred during Pindale era (18,000 years ago)

*Geology forces carved out the Yellowstone landscape thousands of years ago. You can get a sense of the time span that it took by considering that the Grand Canyon of Yellowstone was carved out by the Yellowstone River. In addition, glacial advancement and retreat further marked the land by moving rock.*

1. Vegetation in Yellowstone
   1. Forests cover about 80% of the park, much of that consists of lodgepole pine.
   2. In non-rhyolitic soils, fir and spruce can replace the canopy of lodgepole pines.
   3. Endemic species-plants that grow nowhere else-occur in unusual or specialized habitats.

*As time goes by, vegetation is introduced by successive generations of growth and decay. The roots break up the preexisting rock to form soil and vegetation that is adapted to specific conditions thrives. Conditions in Yellowstone have allowed lodgepole pine species to dominate. Endemic species are present in areas affected by underground heating.*

1. Yellowstone fires of 1988
   1. Burned 36 percent of the park or 798,880 acres
   2. Extinguished by the combination of human effort and weather
   3. Increased the rate of decomposition of the ecosystem

*Not unlike drier habitats surrounded by trees, Yellowstone is susceptible to wildfires that can burn out of control. In 1988, a wildfire burned this way until firefighters were called in to control the blaze. After it was extinguished, 36 percent of the park had burned. The ash added nutrients to the ecosystem that would be later be recycled back into the forests.*

1. Wildlife in Yellowstone
   1. Yellowstone is home to the largest concentration of mammals in the lower 48 states.
   2. Frogs and amphibians are monitored within Yellowstone for measuring ecosystem health.
   3. Home to birds rarely found anywhere, including the peregrine falcon and bald eagle (and at one time the whooping crane)

*Yellowstone is known as one of the most beautiful places in American history because of its rich natural habitat. The park contains the largest concentration of mammals in the lower 48 states, along with amphibians and birds. With the exception of amphibians, wildlife was viewable all the days we visited.*

1. Mammals as Wildlife
   1. Only place in the lower 48 states to have free-ranging bison population
   2. Black bears are common (only couple hundred grizzly bears)
   3. One of the largest herds of elk in the US
   4. Grey wolves were restored in 1995 (>100 now live there)

*For the majority of time that was spent on the roads, there were many opportunities to see wildlife. Most of the time, we could see the wildlife from our cars. The only exception was the grey wolf, possibly due to its recent reintroduction. Seeing the grey wolves required a set of binoculars.*

1. Bison (*Bison bison)*
   1. Largest land mammal in North America (weigh up to 2,000 lbs.)
   2. Hunting in the 1800’s changed the number of bison from 30 to 60 thousand to a few dozen.
   3. In 1968, the bison population was healthy enough to be left alone.
   4. Some of the population have contracted the disease brucellosis
   5. Bison with the disease aren’t welcome by livestock farmers and so aren’t allowed to leave the park

*The most abundant mammal visible on our trip was the bison. Often referred to as “buffalo”, bison is considered more correct because the common name creates confusion with other buffalo. Hunted to near extinction and then brought back by intervention from concerned citizens, bison are now able to stay at sustainable numbers. Brucellosis, a disease that infects bison and livestock, has kept the bison from roaming free. Although, the current plan has drawn a lot of criticism because of how populations are controlled.*

1. Grizzly and Black Bears (*Ursus* sp.)
   1. Only about 50% of the black bears are actually black. Others are brown, blonde, or cinnamon.
   2. Bears are considered true hibernators. They can be easily woken from hibernation.
   3. When faced with a threat, bears are likely to retreat up a tree or flee. Some, such as female with cubs, may attack.
   4. Bear management plan in place to ensure that population remains large, human injury stays low, and property damage is minimized.

*Even though they are quite a rare site, bears can be seen from time to time out in the open. The black bear and the grizzly bear have slightly different appearances, color not being one of them. Bears are true hibernators and use this time to conserve energy during the cold winter months. Bears can become defensive and so we were told that we needed to stay at least 100 yards away. Bear attacks can occur if you’re not careful so managing the population is a top priority at Yellowstone.*

1. Elk (*Cervus elaphus*)
   1. Most abundant large mammal found in Yellowstone.
   2. Probably most photographed because their huge antlers.
   3. Only one herd lives in the park year-round: Madison-Firehole
   4. The northern Yellowstone herd is one of the largest herds of elk in the United States.
   5. Focus of much research on how environmental variability affects reproduction and survival.

*Elk aren’t viewed as much as bison yet are an amazing animal to see due to their huge antlers. Migration routes outside the park do exist and may elk take advantage of them. In fact, only one herd stays within the park year round, the Madison-Firehole herd. Research on populations within the park measure the amount of variability in reproduction and survival due to the environment.*

1. Wolves (*canis lupus*)
   1. By the mid-20th century, wolves were almost entirely eliminated from the 48 states.
   2. Highly social animals that live in packs with leaders, known as alpha male and alpha female.
   3. 1995 – 31 wolves from Canada relocated to Yellowstone.
   4. 2009 – Wolves released from endangered species list in Montana and Idaho.

*Similar to the story of the bison in America, wolves were hunted to very low numbers in the United States until humans intervened with success. The numbers growing yet wolves were just recently released from the endangered species list in the Yellowstone area. Wolves are a treat to watch in the park, some devote a lot of time to it, because of their social behaviors. Packs are led by alpha males and females and they care for their young.*

1. Pronghorn Antelope (*Antilocapra americana*)
   1. Ungulates with deer-like bodies with white patches on belly and backside
   2. Oversized windpipe and heart allow sustained sprints of 45-50 mph
   3. Careful management plan has helped 1.5 million to roam prairelands
   4. Research studies within park seek to answer why population is declining

*Antelope are a common site in Yellowstone, often confused with deer. The park attempts to control the population and perform research on populations to determine factors that influence their numbers. Their speed is unrivaled within the park since they have enlarged hearts and oversized hearts that allow them to sprint at up to 45-50 mph.*

1. Bighorn Sheep (*Ovis canadensis*)
   1. Inhabit high, rocky country thanks to concave feet that allow them to walk over rocks.
   2. Adult males can weigh up to 300 pounds, including horns that can weigh up to 40 pounds.
   3. Males challenge one another by crashing horns together during mating season.
   4. In 1982, pink eye drastically reduced the population (60%) which has been slow to recover.

*Once much more common, you can still see a few bighorn sheep hanging out on the rocks in higher altitudes. Early populations of sheep suffered an epidemic of pink eye and their numbers have not quite rebounded. Their horns are enormous which they use to catch a mate during mating season. They males use them to crash into each other to attract the females.*

1. Yellowstone Geology
   1. Yellowstone is the source of one of the largest volcanic eruptions in history.
      1. Molten rock rising from the Earth’s core created increased pressure on the landmass above it.
      2. Cracks in surface led to quick expansion of gas, sending volcanic ash and magma into the air.
      3. As the underground magma was ejected, the land mass above it sunk to fill in empty space.

*Volcanic eruptions are caused by rising magma within the earth’s crust. As the pressure increased within the ground, the crust cracked and eventually led to an eruption. The land mass resting on top of the ejected magma settled in to fill in the evacuated space.*

1. Hydrothermal Features
   1. The largest concentration of active geysers in the world.
      1. Hot springs with constricted “plumbing”
   2. Fumaroles, or steam vents, create hissing of steam and gases.
   3. Travertine terraces, created by dissolved calcium carbonate, are constantly changing.
   4. Mudpots, contain bacteria that digest sulfur, breaks rock into clay.

*The cracks are still around today and magma still rises underneath the surface. The geologic features of the park are a result of the cooling that occurs near the surface. The combination of heat and water creates the steam which is found in the geologic features. Geysers and hot springs are created through water turning to steam, as well as fumaroles. Travertine terraces and mudpots get their name from the surrounding rock.*

1. Hot Springs
   1. Water, heated by underground magma, rises up through cracks in ground
   2. Heat energy is released slowly leading to colorful features.
   3. Minerals within water can precipitate above ground, such as silica (Si) and carbonate (CO3) compounds

*Hot springs are water features that are very hot which leads to precipitating silica and carbonate compounds. Pools of water appear colorful because of the heat. The water begins to evaporate at the surface and can displace these compounds on the surface, forming structures above the water.*

1. Geysers
   1. Water dissolves silica in nearby rocks as it rises to the surface.
   2. Pressure drops as it reaches the surface causing the water to turn to steam.
   3. Water expands and causes an explosive geyser eruption.

*Hot springs that have constrictions in the underground plumbing build steam and eventually erupt. The water dissolves silica in nearby rocks. As water reaches the surface, the pressure quickly turns the water to steam. Old Faithful is probably the most famous of the geysers and erupts roughly once an hour. Although Old Faithful is the most well-known there are other geysers that are as magnificent.*

1. Fumaroles
   1. Like hot springs but with more heat
   2. Water boils away and releases steam and gases
   3. Also known as steam vents

*If the crack is subject to increased heat and the water boils to the point that steam is the only thing that escapes, then fumaroles will result. The steam is constantly released and hissing can be heard coming from the vent.*

1. Mudpots
   1. Presence of hydrogen sulfide gas leads to the production of sulfuric acid
   2. Sulfuric acid dissolves the surrounding rock
   3. Clay mixed with fine particles of silica form bubbling mudpots

*Dissolved minerals from the surrounding soil can lead to sulfuric acid in the presence of hydrogen sulfide gas. The sulfuric acid causes the surrounding rocks to dissolve and turns to clay. The clay combines with silica to form bubbling mudpots. Bubbling mudpots smell of sulfur and gives them an undistinguishable smell.*

1. Thermophiles
   1. **Extremophile** – microorganisms living in extreme conditions
   2. **Thermophile** – heat-loving extremophile
   3. **Microorganims** – Single- or multi-celled organism of microscopic or submicroscopic size. Also called microbe

*Thermophiles thrive in these conditions due to the hot temperatures surrounding the geothermal features. They are a type of extremophile because they live in extreme conditions. These organisms are often called microbes, or microscopic organisms consisting of one or more cells.*

1. Thermophiles in the Tree of Life
   1. Bacteria
      1. Cyanobacteria
   2. Archaea
      1. Thermococcus
   3. Eukarya
      1. Animals
      2. Fungi
      3. Plants

*Bacteria are commonly mistaken for microscopic organisms or microbes. In fact, there are other types of microbes from eukarya. The domains Bacteria and Archaea consist of unicellular prokaryotes, or bacteria, but Eukarya contains eukaryotes. Multicellular organisms, known as eukaryotes, are organisms like animals, fungi, and plants. However, thermophiles are microscopic unlike other eukaryotes.*

1. Thermophilic Bacteria
   1. Cyanobacteria were the first photosynthesizers, more than 3 billion years ago
   2. All green nonsulfur bacteria photosynthesize, some also chemosynthesize
      1. Change hydrogen or sulfur into forms thermophiles can use
   3. Often join together to form filaments

*Cyanobacteria are known for being the first photosynthesizers more than 3 billion years ago. Along with nonsulfur bacteria, they form characteristic types of thermophilic bacteria found in Yellowstone. Filamentous bacteria form colonies in the form of mats that are visible next to geothermal features.*

1. Thermophilic Archaea
   1. Single-celled organisms with tough outer cell wall that provides protection
      1. Also have protective enzymes within the cell
   2. *Sulfolobus*, most isolated and well known by scientists, exists in sulfuric hydrothermal areas
      1. Oxidizes hydrogen sulfide into sulfuric acid, which dissolves rock into mud
      2. It is parasitized by viruses never before known on Earth

*Archaea are often associated with extremophiles and contain adaptations that allow them to survive in extreme environments. With thermophiles in Yellowstone, a tough cell wall provides protection and the ability to metabolize sulfur gives them the ability to exist in mudpots. An interesting fact is that they are parasitized by viruses that aren’t known to exist anywhere else.*

1. Thermophilic Viruses
   1. Not considered to be alive
   2. Our bodies are too cold to cause problems for humans
   3. Scientists suspect that they exist in Yellowstone’s hydrothermal features
      1. One kind was discovered at Norris Geyser Basin
      2. Another discovered in Midway Geyser Basin

*All viruses are non-living, yet these viruses don’t pose any threat to humans. This is because they exist in areas of the park too hot for humans to be in danger. They are still being researched and little is known about their characteristics.*

1. Thermophilic Eukarya

*Thermophilic Eukarya consist of smaller organisms such as algae and protozoa, as well as flies and plant life. Endemic plant species are found here because of the uncharacteristic hot temperatures found there. The species are adapted to both the temperature and pH, two factors that are important to functioning of all organisms. These organisms are adapted to especially high temperatures and low pH, unusual features among eukaryotes.*

1. Thermophilic Communities
   1. Multiple layers of microorganisms comprise inch-thick mats
      1. Dozens of types of microbes from all three domains can exist there
   2. Changes occur in communities occur as light, temperature, and chemical compositions change
   3. Bison and elk find food and warmth on the less extreme edges of thermophilic environments in winter

*Communities are often found around geothermal features as mats, with a network of dozens of types of microbes existing together. Communities of microbes change as the conditions in the environment change. The communities of microbes serve as food for grazers that exist on the fringe of the geothermal areas.*

1. Thermophiles in Time and Space
   1. Scientists study thermophilic communities looking for evidence of life on other planets
      1. Ancient conditions on Earth which led to life may have developed on other planets as well
      2. Remains left behind, called “signatures”, help scientist understand the environment and evolution on early Earth

*Since the thermophiles are so unique, scientists are beginning to search for other places that these microbes might exist. Specifically, other planets are being searched for signs that these microbes once existed. In addition, thermophiles are being studied here to provide new technologies. For instance, thermophiles were studied in order to make better detergents for washing machines. Other thermophiles were found useful in DNA manipulation…*