Climate Change in National Parks

A Student Activity Guide in Nature's Classroom

Sponsored by the National Parks Foundation

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Introduction

We hear the phrases "climate change" and "global warming" almost every day. There is constant debate surrounding this topic in the news and in politics. The latest Intergovernmental Panel on Climate Change (IPCC) report (2007)[1] stated that "warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level." It is a topic that cannot be ignored. What we don't often hear about is how climate change is affecting America's most beloved natural areas. The National Park Service manages 392 national park units and 58 national parks for the "enjoyment, education, and inspiration of this and future generations." Educating the public, including students, about the importance of national parks is vital for their continued protection.

The idea for a park-centered middle school climate change curriculum evolved from the continued realization that educating our youth is an important way to provide future protection for America's most precious places, and that more and more, national parks are threatened by the potential negative effects of climate change. While national parks are some of the only places in the world where both natural and cultural resources are so well protected, they are not entirely protected from what occurs outside their boundaries. Influxes of exotic species, habitat fragmentation, poaching, and now climate change are all problems that national parks face. Firsthand experiences in these amazing places helps students form important connections to our national parks that inspire them to want to learn more about, and take care of, the natural world.

There are seven national park units that offer extended educational experiences for students. These parks have environmental education institutes located within their borders. The institutes provide multi-day, overnight experiences that enable school students to live and learn inside the park. Three of these national park institutes, along with the National Park Foundation, have collaborated to create this climate change activity and resource guide. Teaching staff from Yosemite Institute, Great Smoky Mountains Institute at Tremont, and North Cascades Institute have joined forces to create a series of lessons and background information to aid educators in tackling this challenging subject matter. The goal is to provide activities that enable students to understand the fundamentals of climate change and how it affects our national parks.

Each day more information and curricula addressing the issue of climate change are created. While there are many different educators and audiences, we all share the challenge of understanding and teaching the complex science behind climate change. It is a matter of understanding not just one, but many intricate systems as well as the roles each of these systems play in the larger picture, much of which is still not fully understood.

The American Academy for the Advancement of Science (AAAS) launched the Project 2061 initiative to help all Americans become literate in science, mathematics, and technology. Their document titled “Communicating and Learning about Global Climate Change: An Abbreviated Guide for Teaching Climate Change, from Project 2061 at AAAS” seeks to convey the ideas and skills that are essential to understanding the science of climate change. The teaching guide in this book is based on teaching standards from the “Scientific Investigations,” “Weather and Climate,” “Use of Earth’s Resources,” and “Interdependence of Life” learning maps from the AAAS document. An outline of the particular standards from AAAS that our lessons address is located immediately following this section. The Project 2061 map approach is valuable in teaching about climate change because it illustrates the relationship of each teaching benchmark to other concepts and ideas, in essence acknowledging the complexity and interrelationships of the many scientific concepts that all fall under the umbrella of climate change.

By introducing students to the science behind the processes that are affecting us and showing them the basis behind scientific conclusions about current and future global conditions, we are giving them the responsibility that comes with knowledge. However, extensive study of human response to ecological crises has shown that knowledge alone is not enough. Environmental educators of all stripes have long known that the best way to get people to care about ecosystems is to immerse them in the natural world and allow them to experience it on their own terms. Bringing our students into the field to investigate climate change and its effects firsthand honors their intelligence and their ability to make decisions as the inheritors of the future that they are.

We would like to extend our appreciation to the National Park Foundation for supporting our national parks and for providing opportunities for students to learn more about America’s special places.

Contributors to this curriculum are:

Yosemite Institute… connects youth to the natural world. Our mission is to inspire personal connections to the natural world and responsible actions to sustain it. Yosemite Institute is one of four campuses of NatureBridge, with campuses in the Marin Headlands, CA, Santa Monica Mountains, CA, and Olympic National Park, WA. Serving over 40,000 participants annually, NatureBridge is the largest nonprofit residential environmental education partner of the National Park Service. Since 1971 we have introduced almost one million students to national parks through field science education programs for schools and youth leadership programs.

www.naturebridge.org
(209) 379-9511

Great Smoky Mountains Institute at Tremont…provides in-depth experiences through education programs that celebrate ecological and cultural diversity, foster stewardship, and nurture appreciation of Great Smoky Mountains National Park for over 40 years. Connecting people and nature summarizes our mission, which we accomplish through providing hands-on learning experiences with the National Park, focusing on developing a greater sense of place, a deepened appreciation and awe for the diversity of life and people, and an ethics of stewardship that follows participants home.

www.gsmit.org
(865) 448-6709

North Cascades Institute…seeks to inspire a closer relationship with nature through direct experiences in the natural world. Our mission is to conserve and restore Northwest environments through education. Since 1986 we have helped connect people, nature, and community through science, art, literature, and the hands-on study of natural and cultural history. Our goal is to help people of all ages experience and enjoy the mountains, rivers, forests, people, and wildlife of the Pacific Northwest – so all will care for and protect this special place.

www.ncascades.org
360-854-2599

Teaching standards addressed in this guide by chapter (paraphrased from AAAS learning maps):

1) Weather and Climate
    a. The weather is always changing, can be measured, and then forecasted. 4B/E5
    b. Climate on earth is variable and is defined by the average weather over time. 4B/M14
    c. Climatic conditions are the result of latitude, altitude, and oceans, as well as other dynamic processes. 4B/H5
2) Hydrology
    a. Liquid water can turn to vapor and when cooled turn back to a liquid or solid, forming clouds, rain and snow. 4B/E3
    b. Water cycles through the earth's atmosphere, oceans, and land (glaciers and snowpack play an important role in this system). 4B/M7
    c. Fresh water is limited in supply and can be depleted or polluted. 4B/M8
3) Earth Systems and Cycles
    a. The atmosphere is a mixture of nitrogen, oxygen, and small amounts of other gases such as water vapor and carbon dioxide. 4B/M15
    b. Plants alter the earth's atmosphere by removing carbon dioxide, making sugars, and exhaling oxygen. 4C/H1
    c. Greenhouse gases in the atmosphere change the thermodynamics of the earth. 4B/H4

    d. The earth's climate has changed throughout history. Today the burning of fossil fuels has added greenhouse gases to the earth's atmosphere which has warmed the climate. 4B/H6

4) Biodiversity and the Dependence of Organisms on their Environment
    a. The world contains a wide diversity of environments and thus a diversity of organisms that depend on those environments. 5D/M1b
    b. Finite resources and other factors limit the growth of populations of organisms. 5D/M3
    c. Changes in environmental conditions can affect the survival of individual organisms and entire species (phenology). 5F/M2b
    d. Human beings are a part of the earth's ecosystems. Human activities have changed the earth in many ways and affect many other organisms. These changes can alter the equilibrium in an ecosystem. 4C/M7, 3C/H4, 5D/H3
5) How Science Works
    a. Scientists often wait until an investigation has been repeated many times before accepting the results as correct. 1A/1
    b. Accurate record-keeping, openness, and replication are essential for maintaining scientific credibility. 1C/7
    c. In an experiment, scientists either control conditions to isolate a single variable, or, when this is not possible, they observe a wide range of natural occurrences to discern patterns. 1B/3
    d. Certain basic beliefs such as the value of evidence, logic, and good arguments are common to all science even though scientific traditions themselves may vary. 1B/4
    e. In the long run, theories are judged by how they fit with other theories, the range of observations they explain, how well they explain observations, and how effective they are in predicting new findings. 1B/6.
    f. The testing, revising, and occasional discarding of theories, new and old, never ends. This ongoing process leads to an increasingly better understanding of how things work in the world, but not to the absolute truth. 1B/7
6) Park Management
    a. The benefit of Earth's resources can be reduced by human activities, such as pollution. 4B/M11bc
    b. The earth has many natural resources of great importance to human life. Some are readily renewable, some are renewable only at a great cost, and some are not renewable at all. 4B/H8

c. Decisions to slow the depletion of energy resources can be made at many levels, from personal to national, and they always involve trade-offs, involving economic costs and social values. 8C/H5
d. Rarely are technology issues simple and one-sided. People's values affect how technology is viewed. 3C/6
e. The value of a given technology may vary for different groups of people and at different points in time. 3B/2

Sources

1) IPCC Fourth Assessment Report: Climate Change 2007, Summary for Policy Makers. Ch. 1, "Observed changes in climate and their effects." Web. June 4, 2010.
2) Center for Research on Environmental Decisions. The Psychology of Climate Change Communication: A guide for Scientists, Journalists, Educators, Political Aides, and the Interested Public. New York. 2009.

Weather and Climate

When teaching about climate change, it is important to define the difference between "weather" and "climate." Weather is the state of the atmosphere at any given moment. When we experience a rainstorm, blizzard, or unusually hot day, we are experiencing weather. When we refer to climate, we are referring to the general weather conditions of a particular place over a period of time, usually 30 years or more. The difference between weather and climate can be summed up like this: Climate informs you of what clothes to buy. Weather informs you of what to wear.

To study climate change, we must first get an idea of what our previous climate was like. In the "Ice Core Exploration" activity, students learn how glaciologists drill into glaciers to find clues to climate change. Students examine their own ice core, measuring past snowfall events that have been frozen into the core's layers. As the students compile their ice core data, a picture of the previous climate begins to emerge.

The largest factor in determining our climate is the sun. However, other features on this planet play important roles, such as latitude, oceanographic circulation, and altitude. The "Orographic Effect" game helps students understand how local and regional climates are influenced by natural features such as mountains and oceans. Students mimic weather patterns observed in the North Cascades National Park by running through an obstacle course while trying not to spill the bucket of water they are holding.

The purpose of each activity in this section is not only to educate the student on a specific topic, but also to explore the connections each topic has to climate change. Each activity should be considered a work in progress. As the information around us is always changing, so too should the way we teach.

Ice Core Exploration

Educator Summary

Climate is defined as the weather of a particular area averaged over a length of time. To get an idea of what the climate was like in parts of the world long ago, scientists can search for clues in ice located in our glaciers and ice caps. Glaciologists use long hollow drill bits to extract cylinders of ice from these ice sheets. The samples of ice that they drill are called ice cores and have identifiable layers of ice created by the compaction of each year's snowfall. Some sheets of ice in the earth's Polar Regions are so thick that we can measure layers of ice from hundreds of thousands of years ago. By counting the different layers, measuring their thicknesses, and performing chemical analyses on the gases trapped inside their air bubbles, scientists can determine what the weather was like during a particular year. By combining the information we receive from each layer of ice, we can reconstruct a history of the earth's climate.

In this activity, students will construct and measure ice cores to simulate work done by glaciologists to study climate. Students will date the layers of their ice cores and graph yearly snowfall data to reveal a climate history.

Key Concepts

- Students will differentiate between weather and climate.
- Students will measure ice cores to study climate history.
- Students will identify how current climate trends impact glaciers in North Cascades National Park.

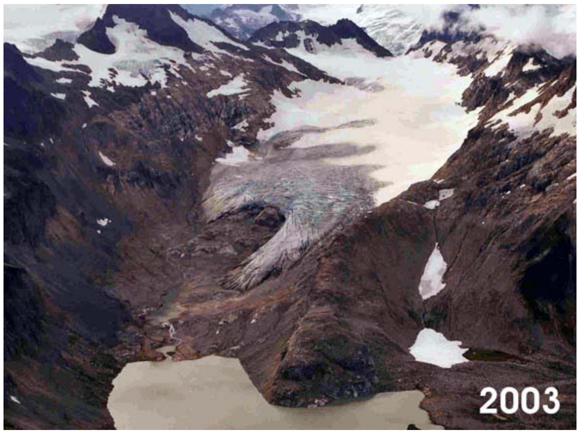
Grade Level: 6th-8th

Time: 60 - 75 minutes

Materials: Ice-core sample sheets, pencils, journal or graph paper, colored pencils or markers, metric rulers, ice core historical temperature graph, calculators, glacier pictures, ice core picture, drilling picture, metric tape measure.

Introduction

Glaciers are amazing natural phenomena composed of thousands of years of compacted ice and snow and have the ability to carve valleys and transform landscapes. Glaciers form in cold Polar Regions or in mountainous regions that receive ample amounts of snow. The North Cascades National Park, with its steep mountains in close proximity to warm ocean currents, receives world record snowfalls and is home to over 300 glaciers.



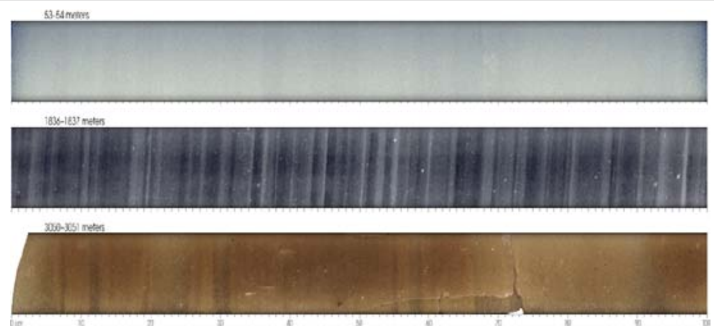
South Cascade glacier, 1979 – 2003. http://ak.water.usgs.gov/glaciology/south_cascade/1979-2003comparison.htm

Within the layers of ice and snow, glaciers hold hints to past weather and allow us to construct climate models for a particular region by analyzing the data we obtain from drilling ice cores. By examining ice cores we can also gather information about the health and longevity of these glaciers.

Procedure

1) Explain to the students that the North Cascades National Park is home to over 300 glaciers. Scientists can study these glaciers by drilling into them and extracting a core of ice. Show them a picture of an ice core. Ask them to make some observations about what they see.

Clear example of layering in an ice core. http://www.amnh.org/exhibitions/climatechange/?section=atmosphere&page=ice_cores



Comparison of ice layer discrepancies at different drilling depths. http://earthobservatory.nasa.gov/Features/Paleoclimatology_IceCores/

2) Inform the students that the layers they notice in the ice core are the result of winter and summer snows. Paired, the light and dark lines form one year of snowfall. By adding the light and dark layers together, we can determine the annual snowfall and gain some insight as to what the weather was like that particular year.

3) Explain that you have brought some ice cores with you for them to study. Divide the students into as many groups as you have ice core segments, and give one ice core segment to each group.

4) Explain that glaciologists can drill ice cores that are thousands of meters long. However, because ice is very fragile, their drill bits are short, and they can only extract one meter of the ice core at a time. Tell the students that they are all holding pieces of a larger ice core. Have them assemble the entire ice core sample by combining their cores in the right order. You may need to remind them that the first core drilled, core sample one, would be the nearest the top of the glacier and thus the youngest layer of ice.

This is the entire ice drilling procedure, showing the relative size of ice core and drilling equipment. *Http://earthobservatory.nasa.gov/Features/Paleoclimatology_IceCores*

5) When the students have finished combining their cores, ask them how many layers they can count. How many years do these layers show a record of?

6) Explain that scientists can date a particular year by looking for clues in the ice. Catastrophic events, like nuclear testing and volcanic eruptions, emit enormous amounts of recognizable particles into the atmosphere that fall to the ground in rain and snow. These particles become trapped in layers of ice and, when found, can be used to identify a particular year corresponding with a particular event. Inform the students that trace amounts of volcanic ash have been discovered in your sample as the result of the eruption of Mt. St. Helens in 1980. Explain that one core has a dotted line on it representing this ash layer. Have the students locate the dotted line. From here, have them date the entire ice core. They can write the dates directly on the core's layers.

7) Have the groups take their original ice core segments and use a ruler to measure and record the width of the summer and winter layers of their sample. Have them total each year's summer and winter measurements to get the annual snowfall for each year. Have them use this information to create a line graph depicting total annual snowfall over time and a bar graph representing each year's summer and winter snowfall amounts.

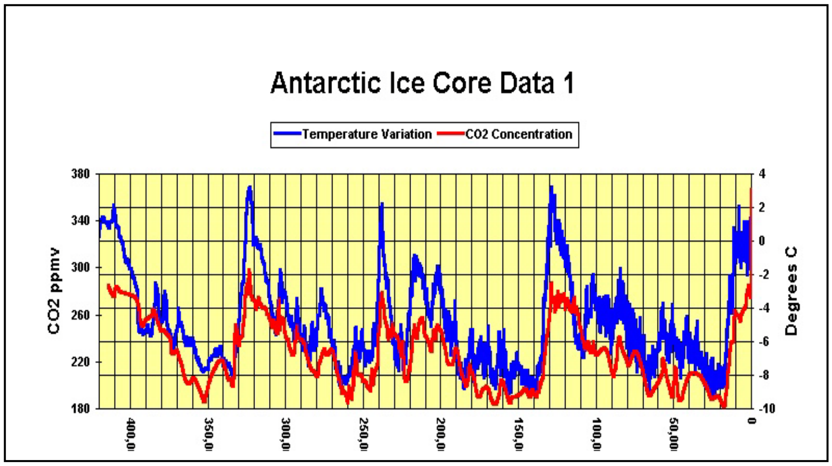
8) Explain to the students that layers in the individual cores help scientists understand what the weather was like during a particular year. Explain to them that weather is defined as the state of the atmosphere in regards to cloudiness, precipitation, temperature, winds, etc at a given time. Our individual layers give us an example of what the weather was like on our glacier in regards to snowfall. Have the students point out which summers and winters had the most and least snow and which years had the most and least snowfall.

Wrap-Up

9) Explain to the students that climate is defined as the behavior of the weather over a period of time. Why would it be a good idea to examine the longer trends in weather rather than just looking at an individual year?

10) To form a climate model of our ice core sample site, have the students average all of their yearly snowfalls. Create one larger graph to depict this information. Include a total average snowfall for the entire core.

11) Tell the students that glaciologists are able to take very deep samples of ice cores that can relay hundreds of thousands of years of climate data. Show them the Ice Core Temperature graph. What do they notice about the data? Are there patterns? What does the chart indicate or suggest about the climate that we are witnessing right now? How will this weather impact our glaciers in North Cascades National Park?



Historical temperature fluctuations
Http://tucsoncitizen.com/wryheat/files/2009/06/460000-years1.jpg

Discussion Questions

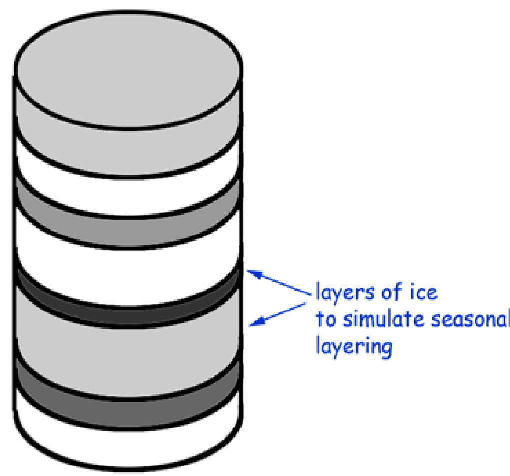
- What do ice cores tell us about climate and weather?
- How can ice cores help us distinguish between weather and climate?
- What was the greatest total snowfall? The least?
- Why is it important to look at the averages rather than single pieces of data?
- Could scientists use ice cores to predict trends in weather?

Variations

A variation of this lesson plan is to examine climate change through dendrochronology, or the study of tree rings. The above activity could be altered by substituting tree cores for ice cores. A specific date on the rings could be pin-pointed by a fire scar that happened on a known date. Students would examine weather and climate through rain and drought conditions in correlation to tree ring growth size.

Diving In

Glaciers and ice sheets form as the result of many, many years of snow accumulation exceeding snow melt. As stated above, winter layers are typically larger and lighter in color, while summer layers are generally thinner and darker. The cause for this color discrepancy stems from the fact that summer snow accumulation is usually less than winter and is subjected to higher temperatures. These temperatures create more freeze thaw events, which lead to a darker, denser layer of ice.



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"What's the Difference Between Weather and Climate?" *NASA*. Ed. Dr. J. Marshall Shepherd, Drew Shindell, and Cynthia M. O'Carroll. 1 Feb. 2005. Web. Apr. 2010.

Check This Out!

- Here is a great dendrochronology variation: http://www.ucar.edu/learn/1_2_2_11t.htm
- Featured Article on the Ice Record: http://earthobservatory.nasa.gov/Features/Paleoclimatology_IceCores/
- A movie showing scientists working with ice cores, "*The Habitable Planet*," can be streamed at: http://www.learner.org/vod/vod_window.html?pid=2280.

The Orographic Effect

Educator Summary

The earth is divided up into three main climate zones: polar, temperate, and tropical. These zones are largely the result of the angle and intensity at which sunlight strikes the earth. Within these large, global climate zones we have smaller, more variable regional climates, and within those, we have distinct local climates. These climates are heavily influenced by surrounding physical features, such as oceans and topography. In mountainous regions, weather on one side of the range is usually quite different from weather on the other side. This is the result of orographic lifting, which causes air currents to rise over mountains, drop copious amounts of precipitation on the side they are coming from, and create arid climates on the side they are moving towards.

In this activity, students will re-create the landscape of North Cascades National Park and mimic the prevailing weather patterns to understand how physical features like oceans and mountains create diverse regional and local climates. In teams, students will race across an obstacle course with a bucket of water to simulate the orographic effect.

Key Concepts:

- Students will understand how sunlight creates global climate zones.
- Students will understand regional and local climates.
- Students will understand how physical features influence climate.
- Students will examine how changes in global temperatures can affect regional climates.
- Students will understand orographic and rain shadow effects.

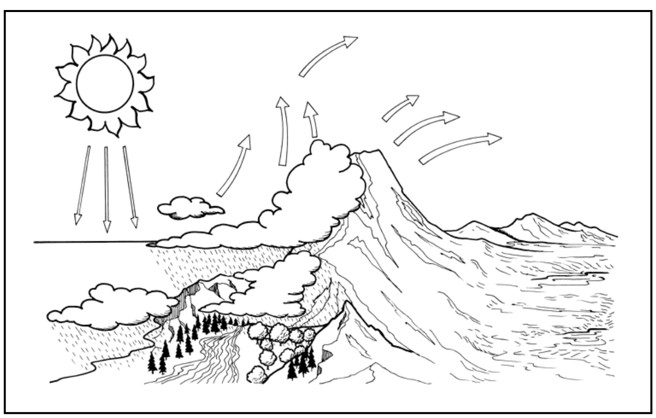
Grade Level: 6^{th}-8^{th}

Materials: Two 5-gallon buckets full of water (or access to a water source like a river or lake), 2 cloud buckets (quart-sized buckets with 3 pencil-sized holes in the bottom), 2 catchment buckets (quart-sized buckets without holes), 2 large cloud buckets (with three pencil-sized holes in the bottom), obstacles to jump over (plastic tubs, etc.), flashlight, softball-sized rock (roughly 10-15 cm in diameter), North Cascades National Park Map.

Time: 30-40 minutes

Introduction

In terms of biodiversity, North Cascades National Park is second only to the Great Smoky Mountains National Park. Our high biodiversity is undoubtedly the result of our complex regional climate. Within the North Cascades ecosystem there are glaciers, temperate forests, rainforests, sagebrush, and ponderosa scrublands. As warm, moist winds blow inland from the Pacific Ocean, this moisture is forced up and over the Cascade Range and into cooler parts of the atmosphere, where it cools, condenses to form clouds, and drops large amounts of precipitation in the form of rain, sleet, or snow. This is called orographic lifting. This leads to temperate rainforests at low to mid elevations and perennial sheets of glacial ice at high alpine elevations. Consequently, because the clouds lose so much of their moisture as they move east across the mountain range, the eastern side of the Cascades receives very little rain and has a dry climate suitable for ponderosa pine and sagebrush. Parts of the east side of the Cascade Range receive as little as ten inches of rain a year. This is called the rain shadow effect.



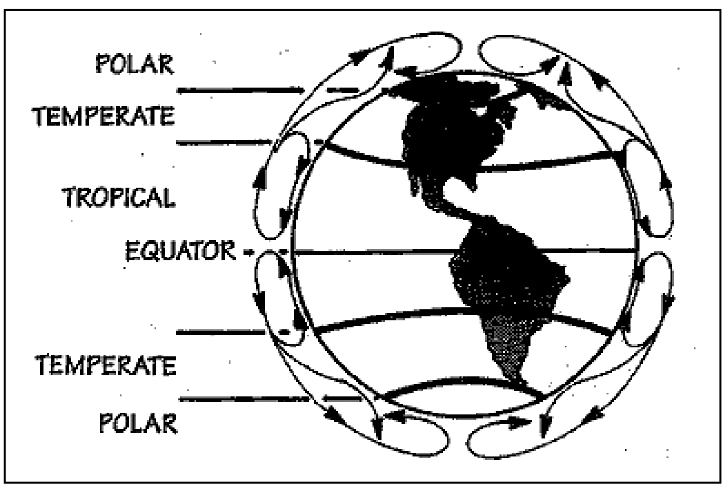
Procedure

Pre-Game Preparations: It is a good idea to set this game up prior to the students' arrival. First, you will need an open area where it is safe for the kids to run. Place two 5 gallon buckets or large tubs full of water at one end of the area, spacing the buckets out several feet apart. This is your starting point. You should place each team's cloud buckets at the start as well. Walk about 15 meters and place 2 small obstacles such as plastic tubs in the path for each team to jump over. This represents a foothill. Continue out another 10 meters and place 2 larger tubs or obstacles. This represents a mountain. Walk another 5 meters and place 2 final smaller obstacles to represent an exit foothill. Continue several more yards and place your catchment buckets.

Game Breakdown: Students will race against each other in teams to fill the empty catchment buckets. Each player will race the course and dump the remains of his or her cloud bucket into the catchment bucket and race back over the course to hand off the cloud bucket to the next runner. Students will race relay style until their team's catchment bucket is full.

Special Note: If you have many students participating in this activity, it may be helpful to set up an additional course for 3 teams to participate.

1) Find a rock a little larger than the size of your fist. This represents the earth. Shine your flashlight on the rock and tell the students that the flashlight represents the sun's light. Ask them to identify where they think the sun's light is the most and least intense.
2) Explain that the earth's climate can be divided into three large categories. These divisions are the result of the amount and intensity of sunlight they receive. Tropical climates are located around the equator where the sun's light is the most intense. Polar climates are located towards the top and bottom of the earth, where the sun's energy is least direct and thus less intense. In between these two climate extremes is the temperate climate, which receives moderate amounts of the sun's energy. Explain that these different climates exist because the earth is round, which causes sun light to strikes the equator directly while hitting the poles at an indirect angle. The direct sunlight on the equator creates hot air that rises and travels away from the equator to the north and south. At the poles, cool air from indirect heating sinks and travels away from the poles to the north and south. As a result, the temperate zone, in between the poles and the tropics, receives a mixture of polar and tropical air and has a moderate climate. Ask: How do you think the weather is different in these three climates? How might plants and animals be different? What adaptations might they have for dealing with their particular climate?



3) Explain that there are other factors that influence our climate besides the sun and latitude. Oceans and mountains can also affect the kind of weather a region receives.

4) Inform the students that you are going to play a game. Divide the students into two groups. Explain that this game is a relay race. Students will dip the cloud bucket into the 5-gallon water bucket and race to the empty catchment bucket across the course. Inform them that they must go over any obstacles they encounter on their courses. Once they reach the opposite end they will dump the remains of their cloud buckets into the catchment buckets and race back to the start, where they will hand off their cloud buckets to a teammate. The first team to fill its catchment bucket wins.

5) Run the game.

6) When one team has filled the catchment bucket, stop the game and congratulate the winners. Thank everyone for playing and inform the students that they have just demonstrated how oceans and altitude influence our climate. Explain that the water source where they dipped their bucket represented the ocean, the bucket they carried was a cloud, and as they ran over obstacles towards the empty bucket they were crossing foothills and mountains. All of the water that they spilled represented rainfall. Ask them why it took so long to fill the catchment bucket (Answer: Because there was very little water (or rain) in their cloud buckets by the time they got to the other side of the mountains).

7) Introduce the terms orographic effect and rain shadow. Explain how orographic lift creates wet and dry regional climates.

8) Explain to the students that you are going to play the game again. However, this time each team will work together to transport the large cloud buckets over the obstacles. The whole team must be helping in some way at all times as they carry the bucket. This tub represents the effects on our climate as the result of a 1^{o}F increase in global temperature. Ask the kids to think about how this might influence the regional climate.

9) Play the game.

10) Discuss what was different in this round. Explain that climatologists believe that as global temperatures increase, the result will be more extreme weather on our earth. In other words, a temperature increase will result in more evaporation from the ocean, which will lead to larger, more saturated clouds (represented by the larger cloud bucket in round two). Inform them that records show that the global climate has

warmed by 1°F since 1970 and that by the end of the next century many scientists believe the earth could warm another 2-3°F.

Wrap-Up

After completing the two rounds, have the students discuss how a change in temperature could impact the plants and animals within regional climates. Pull out a map, and have the students explore the Cascade region. How could warmer weather impact the people in this area?

Discussion Questions

- How does the sun's energy create global climate zones?
- What factors influence regional and local climates?
- How can increases in global temperature impact regional climates?

Variation

Pull out some old magazines and have the students construct visual representations of various regional and local climates created as the result of the orographic effect. In groups, students will cut out pictures of plants, animals, and landforms that are typical of a particular climate. When all the students are have completed this task, have the groups present their posters.

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Check This Out

- An interactive explanation of orographic lifting: http://www.pbs.org/wgbh/nova/kilimanjaro/weather.html

Hydrology

Hydrology, or the study of the movement, distribution, and quality of water on earth, is an important topic of study and one that has direct links to climate change. Increasing our students' scientific understanding of water is crucial to their understanding of larger systems such as ecosystems, climate systems, and geologic systems. In addition, understanding the role water plays within those earth systems helps students understand the positive and negative effects that human activities have on water - and thus on those important natural systems – and links everyday activities like driving a car, taking a shower, or drinking a glass of water to the natural world. Climate change topics are included throughout these hydrology lessons to demonstrate how hydrology and the water cycle affect our earth's climate, how they are in turn affected by changes in that climate, and why we should not only care about those changes but translate that care into responsible action.

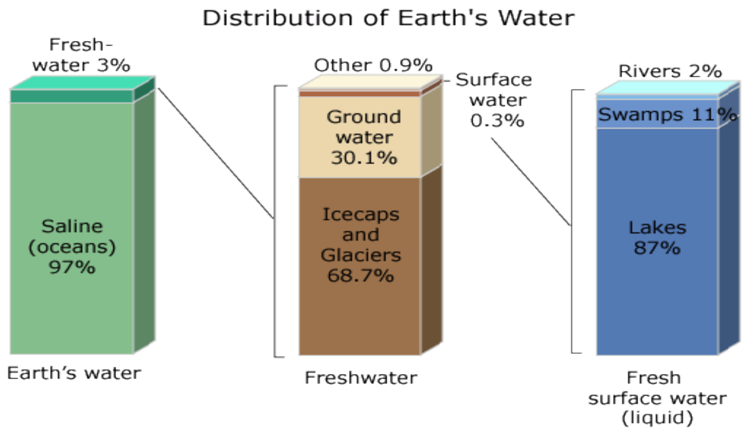
The lesson "Our Precious Resource" shows how fresh water resources available for human consumption are limited in supply and how pollution can alter our water resources. The lesson "It's A Cycle" demonstrates how water changes form and moves around on the earth. Both lessons use hands-on activities that can be completed within the classroom or outdoors.

Our Precious Resource

Educator Summary

It's a paradox that on a planet extensively covered with water (about 71% of the earth's surface) this resource is one of the main limiting factors for life. The amount of water on earth has not changed. Recently, scientists have begun wondering whether or not there will be enough water for the rapidly growing human population.

On a global scale, only a small percentage of water is available for human consumption. There are about 326 million trillion gallons of water on earth. 97.5% of this is salt water. This leaves about 9 million trillion gallons of fresh water, or 2.5% of the total amount of water on earth. Out of this 9 million trillion gallons of fresh water, 69.6%, or 6.3 million trillion gallons, is frozen in ice sheets, glaciers, or permanent snow cover. 30%, or 2.8 million trillion gallons, is beneath the ground in soil and aquifers. The remaining 0.4%, or 31,000 trillion gallons, is the surface water held in lakes, rivers, and wetlands. This amount also includes all the water held in plants, animals, and the atmosphere at any given time.



http://ga.water.usgs.gov/edu/earthwherewater.html

The following activities demonstrate the limited supply of fresh water available for individual humans and entire countries, the decisions we make about water management, and the effects that humans have on the quality and supply of water. The three activities can be completed together as one larger lesson or taught independently.

Activity # 1: A Single Drop of Water

Key Concepts

- Fresh water is in limited supply.
- The earth's fresh water can be depleted.

Grade Level: 6th - 8th with high school variation

Materials: One clear 1000 ml water bottle, two smaller clear containers for water, a cup with ml measurements, eye-dropper, map of the world or globe.

Time: 20 minutes

Introduction

This activity demonstrates the amount of water available for humans in relation to the total amount of water on earth. It can be misleading to see large oceans, have a constant flow of water from our faucets, or even live in a place where it rains often. Water is not endless, and in some places in the world, people travel up to eight miles a day just to get clean drinking water.

Procedure

1) Show the students a liter (1000 ml) of water and tell them it represents all the water on earth.

2) Ask the group where most of the water on earth is located. Show on a map or a globe how about 70% of the earth's surface is covered in water. Now pour 700 ml of the original 1000 ml into another container. The remaining 300 ml represents the amount of fresh water on earth.

3) Ask the group what is at the earth's poles. Almost 70% of the earth's fresh water is frozen in ice caps and glaciers. Pour 210 ml of the 300 ml representing the fresh water into another container to represent the water frozen in ice caps, glaciers, and permanent snow cover. The remaining 90 ml will represent the non-frozen fresh water that is made up of groundwater (beneath the ground in soil or aquifers) and surface water (lakes, rivers, and wetlands).

4) Use an eyedropper to remove a single drop of water from the 90 ml of water representing the ground and surface water, and place this drop in the center of your cupped hand. This single drop represents the clean, fresh water that is not polluted or otherwise unavailable for human use.

5) Discuss the results of the demonstration. Ask the group if there is currently enough water available for people. This is a good time to talk about how much water average Americans use in their lifetimes. On average, a single American citizen will use 85 gallons of water a day. Multiply this daily use by 365 days, and then by 75 years (estimated life span). What did the group find? Discuss ways we can all reduce the amount of water we consume.

6) How is the amount of clean, fresh water on earth linked to climate change? How will climate change affect the amount of water available for human use globally, regionally, and locally? Will this intensify or relieve the pressure on our water supply as our population grows?

Variation for High School Students

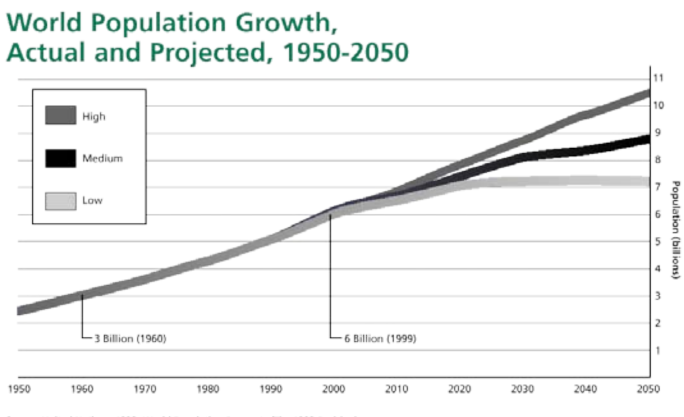
Begin this activity by putting the number 326,000,000,000,000,000,000 on your white board. Explain that this number (326 million trillion gallons) is about how much water there is on earth. All life has to be able to function and survive within the confines of this number. There will never be more or less water on earth. It just changes form.

- Step 1 - Total water (100%) on earth divided among all people (based on a world population of 6.8 billion people) = 48 billion gallons/person
- Step 2 - Subtract 97.5% of each share (46.8 billion gallons) to represent water that contains salt: 48 billion gallons - 46.8 billion gallons = 1.2 billion gallons/person

- Step 3 - Subtract the 69.6% of this water that is frozen in ice sheets, glaciers, and permanent snow cover (8.35 million gallons): 1.2 billion - 8.35 million = 3.65 million gallons/person
- Step 4 – Subtract the 99.5% of the 3.65 million gallons that is unavailable to humans because it is too far underground, polluted, or trapped in living things (3.63 million gallons): 3.65 million gallons - 3.63 million gallons = 2 million gallons/person

Wrap-Up

Tell the group the world's population for years 2005 (6.5 billion), 2000 (6 billion), 1995 (5.7 billion), 1990 (5.3 billion), 1985 (4.85 billion), and 1980 (4.5 billion). The predicted world population for year 2050 is 9.4 billion. Students can document not only how fast our world population is increasing but also how the water supply for each individual human diminishes as the population increases. In 2050, there will be approximately 1,330,000 gallons of fresh water available for each human in his or her lifetime. However, the average American currently uses approximately 2,326,875 gallons of water within his or her lifetime. Finally, these estimates assume that our water supply will not change, but how will this be different because of climate change's effects on hydrology?



http://www.unfpa.org/6billion/pages/worldpopgrowth.htm

Discussion Questions

- Where is the majority of water on earth?
- How much water, in relation to the total amount of water on earth, is available for human consumption?
- How would an increase in the world's population affect the amount of water each individual can use?
- What are some ways we can reduce our water consumption?
- How does climate change effect water supply globally, regionally, locally, and individually?

Activity #2: Our Water Footprint

Key Concepts

- Fresh water is in limited supply.
- Countries around the world have different amounts of fresh water available to them.
- Water is used in many ways for many purposes.

Grade Level: 6th - 8th

Materials: 4 yellow, blue, green, and red 8 x 10" laminated cards, 12 laminated "chance" cards, map of water footprint by country, pie graph of US water usage.

Time: 1 hour

Introduction

This activity is played as a game. Each student will represent a different country. They will each be making decisions on how they will spend their water points in order to provide everything from basic survival needs to luxurious amenities.

Procedure

In preparation for this activity:

- Paste the table below onto one side of each colored 8 x 10" card
- On the other side put a number 1 - 4 for yellow cards, 5 - 8 for blue, 9 - 12 for green, and 13 - 16 for red
- Laminate each card
- Paste one "chance" event on each of the 12 chance cards
- Laminate each card

Country Playing Card

Industrial	Commercial	Agricultural	Residential	Technological
5	5	5	5	5
4	4	4	4	4
3	3	3	3	3
2	2	2	2	2
1	1	1	1	1

Country profiles:

- Yellow countries: Numbered cards 1 - 4 - These countries have higher functioning power abilities. These countries have to allot 1 water point for industry every year.
- Blue countries: Numbered cards 5 - 8 - These countries are located next to an ocean. They have access to extensive supplies of saline water. These countries have to allot 1 water point for commerce every year.
- Green countries: Numbered cards 9 - 12 - These countries have access to large amounts of fresh surface water. These countries have to allot 1 water point for agriculture every year.
- Red countries: Numbered cards 13 - 16 - These countries are located in the rain shadow of a large mountain range and are land locked.

1) Begin by passing out the colored cards to the group so that each student has a card. Pair up the students if you have a larger group, and use fewer cards with a smaller group. Give each student some time to be creative and come up with a name for their country.

They will be acting as presidents of their countries. Tell the group there is no winner or loser in this game. The objective is to see water availability and usage in different countries.

2) In the first round (year 1), each country is given two water points. The students can use little pebbles, twigs, or pieces of dead leaves for their water points. The water points will be placed on the boxes under the different categories; they represent how far along each country is in terms of that particular category. Each country can only go up one level per category each year. After the students have placed their water points, read off to them how their countries have progressed based on their decisions.

3) At the beginning of the second round (year 2), and every round from here on out, have one student pick a "chance" card and read it aloud to the group. Have the students place their allotted water points based on:

- What color country they are (yellow countries have to place one water point in industry every year, blue for commercial, and green for agriculture)
- The chance cards give and take water points for certain countries every year. For example, sometimes certain countries will not be given a water point for the year.
- The higher each country moves within each category, the more water points they are allotted per year.

4) Level breakdown:

Industrial

- Level 1 - Your country is able to use simple harvesting methods for wood and produce primitive wooden structures.
- Level 2 - Your country is able to use simple mining techniques for iron, coal, and gravel. Electricity is discovered: +1 water point a year.
- Level 3 - Raw materials are being harvested on a large scale: +1 water point a year.
- Level 4 - Thermoelectric power is being produced on a large scale with steam-driven turbine generators: +1 water point a year.
- Level 5 - Your country has reached its maximum energy production: +1 water point a year. In addition, you must continue to allot 1 water point for industry that will now be exported to another country of your choice.

Commercial

- Level 1 - Local distribution of limited lumber and food supplies can occur within communities.
- Level 2 - Distribution of goods can occur between communities.
- Level 3 - Markets are developing and becoming widespread: +1 water point a year.
- Level 4 - Transportation and distribution of manufactured goods becomes more efficient: +1 water point a year.

- Level 5 - Exportation of water points to other countries gives you +1 level of your choice.

Agricultural

- Level 1 - Hunting and gathering methods are used.
- Level 2 - Edible plant seeds are now being planted and harvested as crops.
- Level 3 - Animals are now raised for meat production and fertilization has been discovered.
- Level 4 - Irrigation systems are discovered; drilling for groundwater is limited: +1 water point a year.
- Level 5 - Groundwater and irrigation systems are fully developed: +1 water point a year. However, you are now overproducing food for your country and there is a population boom: -1 water point a year.

Residential

- Level 1 - People travel miles for access to drinking water.
- Level 2 - Half of your country's population continues to travel far distances for water, while the other half has very limited local supplies of water.
- Level 3 - Basic water towers are developed, so all households can have limited access to local drinking water.
- Level 4 - Advanced water towers are developed so all households can have comfortable amounts of water for drinking, sanitation, and food preparation: +1 water point a year.
- Level 5 - People are able to use water freely for all necessary purposes including washing clothes and taking showers as well as any leisure and recreational activities: +1 water point a year.

Technological

- Level 1 - Communication is limited to within communities.
- Level 2 - Basic roads are developed with animal powered transportation methods.
- Level 3 - Sanitation has improved.
- Level 4 - Hydropower was developed: +1 water point a year.
- Level 5 - Communication, alternative sources of energy, sanitation, and transportation are at their maximum potential: +1 water point a year.

5) "Chance" cards:

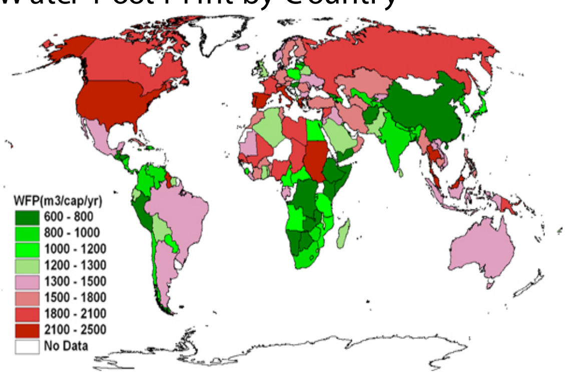
- A drought hits all red countries for the year: -1 water point.
- An underground spring begins releasing fresh water in the green countries: +1 water point.
- A large bug infestation devours many of the green countries' crops: agriculture drops 1 level.
- Desalination plants are developed in the blue countries: +1 water point.
- A sand storm hits the red countries for the year: -1 water point.

- Oil is discovered in the yellow countries: +1 water point.
- Internet breakthrough for yellow and blue countries: +1 water point.
- A deadly disease spreads through the green countries: -1 water point.
- Pirates invade the docks of the blue countries: -1 water point.
- Earthquake strikes red countries: -1 water point.
- Tornadoes blow through red countries: -1 water point.
- The citizens of the red countries are drinking dirty water and many become ill: -1 water point.

Wrap-Up

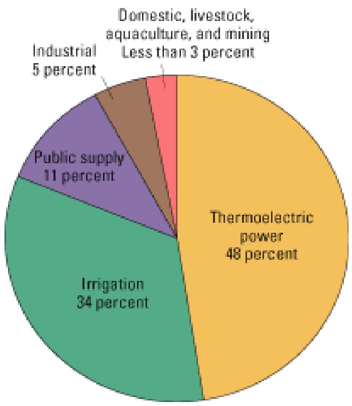
After a student has filled his or her board you can stop and have a conversation about the activity. Show the group the picture of the world's water footprint by country. Ask the students, who filled their boards (usually a yellow country) how many water points they were placing on in the last round (should be about 5 or 6). Explain that the yellow countries from this activity represent the countries with a large water footprint. Take the U.S. as an example, and talk about what we use water for. Show the pie graph of U.S. water usage. You can also give the group some of the facts about water consumption from the "Diving In" section at the end of this lesson and add in the potential effects of climate change on water resources.

Water Foot Print by Country



Chapagain, A.K., and A.Y. Hoekstra. "Water Footprints of Nations: Water Use by People as a Function of Their Consumption Pattern." <u>Water Resources Management</u> (2006).

United States Water Use



Discussion Questions

- What are some ways water is used around the world?
- Do all countries have access to equal amounts of water? Why not?
- What are some characteristics of the countries with larger water footprints?
- How do the people of these countries consume water?
- Will the countries with larger water footprints be able to continue to use water the way they currently are forever? Why not?
- What are some characteristics of countries with smaller water footprints?
- How might climate change effect different countries' water availability and use?

Activity #3: Watershed Health

Key Concepts:

- Water can be polluted.
- Students will understand the correlation between personal decisions and watershed health.

Grade Level: 6th - 8th

Materials: Large, clear container 1/4 full of river water; large bucket full of river water, scenario cards, lemon juice, gravel, 2 plastic spoons, 2 plastic cups, 4 water testing jars, pH testing kit, eyedropper, coin to flip, makeshift fishing pole, 4 laminated paperclip salmon pictures, 4 laminated macroinvertebrate pictures.

Time: 45 minutes

Introduction

Explain how together we will be creating a story about a beautiful river. Tell the group that this story is about how rivers can change with the decisions that we make about land use within our watersheds. Put the students in pairs, and give each pair a scenario card. Ask each group to read their scenario card silently and think about it. Tell the students that they will be representing individuals that live in the watershed. Inform them that later they will be reading their card aloud and then will be asked to make an important decision based on a question posed by the instructor.

Procedure

1) In preparation for this activity:
   - Cut out and laminate the words "SHELTER," "CCW," and "DO." Place them on the bottom of your large clear container that is 1/4 full of river water.
   - Cut out and laminate pictures of four different macroinvertebrates. Place Velcro or tape on the backside of these pictures.
   - Cut out and laminate pictures of four different types of salmon. Attach a small bobber (or any floatation device) to the dorsal fin and a paper clip to the mouth of each salmon.
   - Laminate and number index cards with each scenario.
   - Tie a small piece of fishing line to the end of a stick and attach a bent paper clip to the end of the fishing line.

2) Begin the activity by passing out the scenario cards. After each group has had time to read over its cards, have the first group read its scenario out loud to the group. Next, read the instructor section of the scenario out loud to the group. Give each group 30 seconds to make a decision based on the scenario. After the group has verbalized its decision, read the corresponding result to the group. Have the group perform the actions that go with its decision. Do this for each scenario.

3) Scenario #1: My partner and I love to spend time down by the river. We just got new bikes and were thinking about riding them along the riverbank.

   Instructor: Will you and your partner decide to ride along the river, or will you decide to ride on bike trails or roads?

   - <u>Ride on the riverbank</u>: Riding alongside the riverbank can cause erosion. Add one spoonful of gravel each to the river.
   - <u>Ride on Trails or Road</u>: Trails can be specially constructed for bike use. Trail builders keep in mind the problems caused by erosion. By choosing not to ride on the riverbank, you won't contribute to erosion problems. Add a cup of water each to the river.

4) Scenario #2: My partner and I love to garden and have started a garden at my house. We are growing corn, carrots, lettuce, and tomatoes, but we've had a little trouble with bugs lately.

Instructor: You and your partner can either spray the garden with bug-repelling chemicals, or research to find alternatives such as other insects that will fight the ones eating your plants.

- <u>Chemicals</u>: When you added chemicals to your garden, they didn't just stay on the plants; they moved with the rain into the soil and eventually worked their way into the river. Add two droplets of pollution each to the river.
- <u>Bugs</u>: There are natural predatory bugs that gardeners can use to fend off pests. This requires no use of chemicals. Because you aren't adding any pollution to the water, add a cup of water each to the river.

5) Scenario #3: My partner and I enjoy spending time by the river. We noticed an area near where we live that didn't have any plants growing on the bank. We are a little worried that the soil is washing into the water.

   Instructor: You and your partner love to mountain bike. You want to clear some shrubs and other understory plants in your neighborhood wooded area for some local trails. On the same weekend you were invited to join a streamside tree-planting event. What will you do? Trail building or tree planting?

   - <u>Trail building</u>: A few months after you cleared the understory, a big storm moved in, and it rained for a week straight. Because you didn't help with the tree planting, there weren't enough plants alongside the river to hold the soil, and it washed down into the water. Add two spoonfuls of gravel each to the river.

   - <u>Tree Planting</u>: You and your partner decided to spend the day planting trees and made excellent progress. A month later, a big storm came in and it rained for a week straight. Because there was vegetation alongside the river, thanks to your work, there were roots to hold the soil in place, and hardly any washed into the river. Add a cup of water each to the river.

6) Scenario #4: My partner and I are macroinvertebrates that live in the river. We need clear, cold water to survive and plenty of shelter so we won't be eaten.

   Instructor: You and your partner need clear, cold water, dissolved oxygen, and shelter in order to survive. Look down into the river, and see if you can read the letters "CCW," "DO," and "SHELTER."

   - <u>Yes</u>: Stick pictures of macroinvertebrates to the side of the bucket. You survived!
   - <u>No</u>: Unfortunately, because of erosion, there isn't good enough habitat for you to survive. Sorry!

7) Scenario #5: My partner and I are students studying the health of our local watershed for a class project. We would like to use our testing skills to see if this river is healthy.

Instructor: You have the skills to test the water quality of our river. Take a bottle and fill it almost to the top with river water. Now, each partner will add 4 drops of pollution indicator to the bottle. Place the cap on top and give it a little swirl. What color is it now? The purple indicator will react with pollution, turning the sample pink. What do you think of your sample?

8) Scenario #6: My partner and I are salmon. We have just transformed from alevin (small larval fish) to fry and are looking for a good place to live with plenty to eat.

Instructor: You and your partner need CCW, DO, shelter, and macroinvertebrates to eat in order to survive. Look down into the river and see if you can read the letters "CCW," "DO," and "SHELTER."

- <u>No to all</u>: None of you survived. Because of soil erosion you don't have the kind of habitat you need.

- <u>Yes to 1, 2, or 3</u>: Add one fish each for each word you can see. Some of you will be able to find enough habitat to survive, but you won't all make it. Erosion has limited the amount of habitat available for you.

- <u>Yes to all</u>: Fantastic! The river is healthy and free of excess soil. You have the things you need to survive.

9) Scenario #7: My partner and I came to the river to go fishing. We are really hoping to catch some salmon to take home for dinner.

Instructor: When salmon runs are low, fishing is limited. If they are high, there are more than enough fish to go around. You and your partner get 15 seconds each to catch some fish. Good luck!

<u>Group Activity</u>
Rainstorm: The National Weather Service has issued a severe thunderstorm warning for the Skagit Watershed. (Stimulate a rainstorm by leading the group in snapping and clapping exercises. End by reducing the student-generated noise to quiet drops.) It just rained for two days straight. Let's check out what has happened in the watershed. (Have a volunteer flip a coin.)

- <u>Heads</u>: A larger area of land has been cleared to make room for a skyscraper. Unfortunately, because there was no vegetation to hold the soil in place during the storm, the rain carried the soil into the water. As a result of the increased sediment load, salmon eggs suffocated and macroinvertebrates died. Remove a salmon and a macroinvertebrate picture from the side of the bucket. Everyone add one scoop of gravel to the river. In addition, fertilizers that were in the soil were also carried into the river. Add 3 drops of pollution to the river.

- Tails: Restoration work done by concerned people living in the Skagit Watershed worked wonders. The trees that were planted and the vegetation that has been protected held strong and stopped the soil from eroding. The watershed is in good shape. Add two cups of water to the river.

10) Scenario #8: My partner and I are very good about brushing our teeth. We brush every morning before school and every night after bed, just like the dentist told us to.

    Instructor: Do you and your partner leave the water running while you are brushing your teeth or do you turn it off until you need it?

    - Leave it on: Letting the water run while you are not using it takes water out of rivers, lakes, and reservoirs. Take a cup of water each from the river.

    - Turn it off: By turning the water off when you aren't using it, you don't take unnecessary water from the rivers, lakes, and reservoirs. You can each add a cup of water to the river.

11) Scenario #9: My partner and I just realized that our car has been leaking oil. We know we have to get it fixed right away.

    Instructor: You have enough money to either get the oil leak fixed or get a new CD player installed in the car. What will you do?

    - Car fixed: By fixing the car, you prevented pollution from working its way through the watershed to the river. You can each add a cup of water to the river.

    - CD player: Because you didn't fix the car, oil continued to leak. It fell onto the ground, was washed into the soil with the rain, and worked its way down into the river. Add 3 drops of pollution each to the river.

12) Scenario #10: My partner and I just got a new car. We are very proud of our car and hate to see a speck of dust on it, so we wash it in the driveway every day.

    Instructor: Even though you live several miles from the nearest river, you still live within the watershed, and your choices will affect the river. Using lots of water to wash your car takes water away from rivers, lakes, and reservoirs. Take one cup of water each out of the river. In addition, soap is not healthy for animals and insects that need the river for habitat. Add 2 drops of pollution each to the river.

13) Scenario #11: My partner and I are biologists studying the health and quality of this watershed. We are going to use our testing skills to analyze a sample of this water.

    Instructor: Take a bottle and fill it almost to the top with river water. Now, each partner will add 4 drops of pollution indicator to the bottle. Place the cap on top and give it a little swirl. What color is it now? The purple indicator will react with pollution, turning the sample pink. What do you think of your sample?

Wrap-Up

Even if the color in the test tubes does not seem to change very drastically, you can remind the students that they have only added a small amount of pollution to a big river, so it may not have a visual impact. However, if hundreds or thousands of people started moving to the Skagit Valley and all washed their cars and left the water running while they brushed their teeth, imagine how much more polluted the river would become.

It would be helpful to find a way to make the pH color testing more drastic when the river is polluted. One suggestion would be using less water in the Skagit River bucket. Another would be adding full squirts of lemon juice to the river when drops of pollution are suggested in the activity directions. Also, think about adding gravel along with drops of pollution to the scenarios where erosion is the result of student decisions.

Discussion Questions

- How do humans impact water supplies?
- What are some causes of pollution to our water supplies?
- How does pollution affect the food chain?
- What are some alternative choices humans can make to reduce the amount of pollution we create?
- What are some ways we can restore currently damaged water sources?

Diving In

Some interesting facts on water consumption: 1,857 gallons of water used to produce 1 pound of beef, 1,382 gallons for a pound of sausage, 756 for pork, and 469 for chicken, 589 gallons for a pound of processed cheese versus 371 for a pound of fresh cheese. During the life of one meat cow 808,400 gallons are used for the 18,700 pounds of pasture, feed and hay plus 6,300 gallons for drinking and 1,900 gallons for cleaning stables and farmyards. This adds to 816,600 gallons of water used during the life of one cow.

Golf courses use an average of 2 billion gallons of water a day for irrigation in the U.S. Americans use about 100 gallons of water at home each day. Millions of the world's less fortunate survive on fewer than 5 gallons per day. People in developing countries walk an average of 3.7 miles to get water. 3.3 million people die from water-related health problems each year.

The longest water tunnel supplying New York City is 85 miles long and leaks up to 35 million gallons a day. Dam projects have displaced up to 80 million people worldwide. U.S. swimming pools lose 150 billion gallons to evaporation every year. In a single toilet flush, 4 to 5 gallons are used. During a shower, 7 to 10 gallons of water is used per minute.

It's A Cycle!

Educator Summary

The water on earth moves in a continuous cycle. This is called the water cycle, also known as the hydrologic cycle, and it describes the movement of water between the atmosphere, the surface of the earth, and below the surface of the earth. In the water cycle, the sun heats the surface water, causing it to evaporate and turn into water vapor, or gas. This water vapor rises into the atmosphere where it cools and condenses into clouds. As the amount of water in the clouds increases, the drops become too heavy and fall to the earth as precipitation (liquid if rain, solid if snow or ice). After precipitation, water is temporarily stored in lakes, glaciers, ice caps, the ground, and living organisms. Humans use water for many things including agriculture, industry, and daily life. Water moves around on land in rivers and streams that eventually lead to the ocean. At any point in this process, water can evaporate back into the atmosphere and continue the cycle.

The following lessons are designed for students to observe firsthand how water changes forms and moves around on earth. These two concepts are written as one lesson with two different activities which could also be used independently.

Activity #1: Water's Different Forms

Key Concepts

- Water has three forms: liquid, solid, and gas.
- Water can change forms through heating and cooling.

Grade Level: 6th - 8th

Materials: An open area outside

Time: 20 minutes

Introduction

Have students go into an open area, preferably outside. Tell them they are each going to be a water molecule.

Procedure

1) Explain to the group that there will be one person who is the caller. This person will call out either "glacier," to represent the solid form of water, "river," to represent the liquid form of water, or "vapor," to represent the gas form of water.

   When the caller says, "glacier," the group will all come together as tightly as possible around the caller with very little movement to represent a large block of ice.

   When the caller says, "river," the group will all hold hands and move in a circle at a relaxed pace around the caller to represent moving water.

   When the caller says, "vapor," the group will all run around the open area in random directions to represent gas.

2) Once the group has the idea the caller can speed up the pace and change the order of commands to represent the speed and randomness with which water can change forms.

Wrap-Up

Take a breather and discuss the three states of water. Ask the students how water molecules behave for the three different states. Ask the group if they think water can go from a solid state right to a gas, and introduce the process of sublimation, in which water changes from solid to gas without ever being liquid. A good example of this is when dry ice gives off gas.

Discussion Questions

- Give an example of water in each form and explain how the molecules behave.

Activity #2: Micro Water Cycle.

Key Concepts

- Water cycles through the earth's atmosphere, surface water, and land.
- Water cycles by processes called evaporation, condensation, precipitation, transpiration, and saturation.

Grade Level: 6th - 8th with high school variation

Materials: One large plastic container, two equal-sized clear plastic bottles (One of the bottles will need to be able to fit into the large plastic container standing upright), plastic wrap, thermometer, tape, water, soil, one rock that will fit into the plastic bottle, some small twigs that will fit into the plastic bottle, some small leaves, pine needles, or moss that will fit into the plastic bottle, an ice cube that will fit into the plastic bottle, an annual precipitation map of your state, pens/pencils, and a journal to document observations.

Time: 30 minutes to prepare and a full day to observe

Introduction

Even though the water cycle is happening all around us every day, it is hard for students to understand all of its stages and processes. This activity introduces the processes of evaporation, condensation, precipitation, transpiration, and saturation by creating a micro water cycle that students can observe firsthand and even manipulate and experiment on. Seeing the forces behind these processes and the effects they have on the water in this micro system will help students understand the water cycle at the watershed and even the global level.

Procedure

1) Explain to the group that we will be creating our own micro water cycle. After we prepare the experiment, we will check in on it at different times throughout the day to record our observations.

2) Begin by filling the large plastic container halfway with water. Place one of the two clear plastic bottles in the middle of the larger container. Fill the bottle 1/4 full of soil. Put a thermometer in the large plastic container. Cover the larger plastic container with clear plastic wrap, making sure it is sealed. Place the container in a sunny location and make your first observations. Discuss evaporation, the process by which water is converted from liquid to vapor. This is how water is transferred from the surface of the earth to the atmosphere. Evaporation from the ocean amounts for 80% of the precipitation back to the earth's surface. Discuss the three main factors that increase and decrease

evaporation: wind, temperatures, and humidity. Have the group record what they think the conditions are inside the micro water cycle.

3) After an hour, come back and make a second round of observations. Note the thermometer, the water level in the large container, and the water droplets on the underside of the plastic wrap. Discuss condensation, the process by which water vapor in the air changes into liquid form. This process is responsible for the creation of clouds, the water that forms on the outside of a glass of ice water, and the water that forms on the inside of a car windshield when many people are in the car. Place a small rock on top of the plastic wrap directly over the bottle in the center of the container. Have the group make observations of what happens to the condensation on the inside of the plastic wrap. Discuss precipitation, the process by which water is released from clouds in the form of rain, freezing rain, sleet, snow, or hail. Show an annual precipitation map of your state. Ask the group to point out the areas of the state that receive the most and the least amount of water a year and discuss why they think that might be.

4) Move the micro water cycle to a shaded area and leave for another hour. Come back and record your observations. Note the thermometer, water level in the large container, and the water droplets on the underside of the plastic wrap. After the group has made their observations, remove the plastic wrap and take the bottle with the soil out of the large container. Make observations of the soil's saturation level. Saturation is the process in which water moves into the earth.

5) After the demonstration on saturation, put the thermometer, rock, twigs, leaves, pine needles, and ice cube into the bottle with the soil. Talk about what each of these items represents within our water cycle ecosystem. Take the other plastic bottle and tape it upside down over the top of the first bottle. Have the group make observations on the temperature, saturation level of the soil, and level of condensation in the top bottle.

6) Leave the water cycle ecosystem in a sunny place for an hour. After an hour make your observations. Observe the foliage in the ecosystem and talk to the group about transpiration, the process in which plants release water vapor to the atmosphere as a result of photosynthesis. Note the ice cube and discuss the process of snowmelt from glaciers and permanent snowfields. Note the level of condensation in the top bottle, the saturation level of the soil, and the temperature on the thermometer.

Wrap-Up

Review the processes of the water cycle after the group has made the final round of observations. Discuss the environmental conditions that can have an effect on the water cycle. Have each student write a summary of what happened from the start of the demonstration to the end that includes their observations and findings.

Discussion Questions

- What is the water cycle?
- What conditions can affect the water cycle?
- Why are glaciers and permanent snowfields important for surface runoff within the water cycle?
- What role do plants play within the water cycle?
- How will an increase in our climate's temperature affect the water cycle?

In the Classroom

Activity #1 works well inside as long as the area is large enough for the group to run around. Activity #2 can be prepared within the classroom, but the activity itself requires both sun and shade. Discussion and wrap-up can be completed indoors.

Variation for High School Students

The scientific method can be introduced and applied throughout Activity #2. Try setting up water cycles representative of different ecosystems and have students create hypotheses for each. With a more equipment, students could measure temperature differences, condensation levels, and saturation levels for each ecosystem. After the data collection process, the students could analyze their data to either support or reject their initial hypotheses. The students can present their findings to each other, compare them to the actual ecosystems, and discuss how the experiment could be improved to better replicate the water cycles of different ecosystems.

Sources

Project WET: Curriculum & Activity Guide. Bozeman: The Watercourse and Western Regional Environmental Education Council, 1995. Print

Kingsolver, Barbara. "Water is Life." *National Geographic* April 2010: 36 - 49. Print

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Earth Systems and Cycles

Climate change will have wide-ranging and complicated impacts on the systems and cycles on earth. We have chosen to examine the atmosphere and the carbon cycle in detail. This section includes a review of the layers of the atmosphere for the instructor and briefly discusses how carbon dioxide is involved in climate change. "Check This Out" includes links to useful websites that describe in more detail the role of carbon dioxide in climate change. The carbon cycle game will teach students where carbon is in the environment and the mechanisms for carbon movement both naturally and through human activity. Finally, the City Planners lesson will explore the use of fossil fuels in our daily lives, how communities impact natural areas through pollution, and the planet-wide affects of climate change.

Atmospheric layers diagram produced by NOAA.

Diving In – The Atmosphere

The Earth's atmosphere is a thin layer, like a blanket, surrounding our planet. This blanket is made up of a few main molecules: it is 78% Nitrogen, 21% oxygen, 0.9% argon, and 0.04% carbon dioxide. There are a few trace elements also, including water vapor and ozone, among others. Our atmospheric blanket of gas molecules has several layers that are distinguished by their temperature, density, and movement.

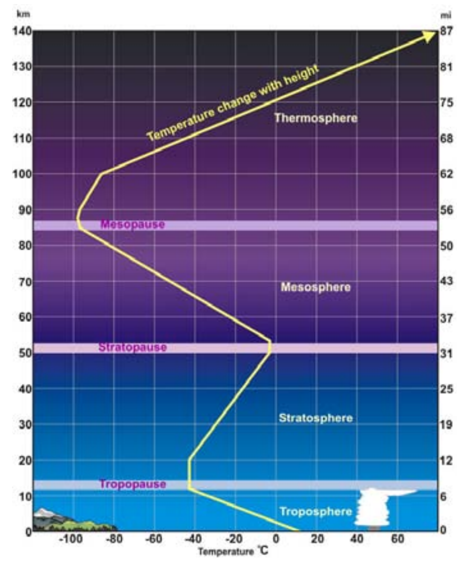
Imagine that you are approaching the Earth from space: the first layer of the atmosphere that you pass through is the exosphere, at 6,200 miles above the planet's surface. Within the exosphere, atoms and molecules escape into space and satellites orbit the planet.

As you continue towards earth, you enter the thermosphere, or upper atmosphere. Gas molecules in this layer no longer escape and are very far apart. Solar radiation in the thermosphere leads to high energy levels, which causes high temperatures. However, it would still feel cold because the molecules are so far apart. As you approach the bottom of the thermosphere, the temperature becomes colder as the energy being absorbed by the air molecules decreases. The absorption of radiation within the thermosphere results in some molecules becoming ionized or electrically charged. These charged molecules form the ionosphere within the thermosphere. The ionosphere can bounce radio signals transmitted from the earth, allowing places all over the world to be reached by radio.

Leaving the thermosphere behind, you enter the mesospher**e.** Temperatures will begin to increase as you descend, but will still not rise above 0^{o}C. Gas molecules become more abundant as you move down, eventually becoming thick enough to slow down and burn up meteorites.

The stratosphere is next. The relatively high temperatures and dense oxygen molecules result in the formation of ozone and the ozone layer. Ozone molecules absorb UV radiation, protecting life on earth from this potentially damaging energy. One form of air pollution, chlorofluorocarbons (CFCs), makes it into the stratosphere and can break down this important ozone layer. Temperatures start to decrease again as absorption of solar radiation decreases in the lower reaches of the stratosphere.

Finally, you enter the lower atmosphere or troposphere. Harmful radiation has been filtered out of the atmosphere by the higher layers, water vapor is in abundance, and gas density increases as you move down through the troposphere all the way to the surface of the earth. This layer, the one in which we live, holds the pollution we put into the atmosphere. Carbon dioxide, both natural and human-caused, exists entirely in this layer. The carbon dioxide acts like the glass roof in a greenhouse. Some of the energy entering the earth's atmosphere makes it all the way to the surface as visible light. Objects on the surface absorb this light and emit some of it as energy in another form: heat. Some of this heat energy is reflected back into the atmosphere. Carbon dioxide, a natural part of the atmosphere, absorbs this heat energy. The burning of fossil fuels by humans increases the amount of carbon dioxide in the atmosphere, therefore increasing the amount of heat energy able to be absorbed in the troposphere and raising the temperature of the earth.



Carbon Cycle Pathways

Educator Summary

The goal of this lesson is to introduce the complexity of the carbon cycle to students. By the end of the game, students should understand that carbon can take many forms throughout the carbon cycle, and that there is no set pathway in the cycle. The game is played in two rounds. In the first round, students become familiar with the forms of carbon and where they occur in the cycle. In the second round, human influence on the carbon cycle is removed to demonstrate the impact we have on the carbon cycle. This activity can be done as a pre-trip lesson to introduce concepts that will be explored in depth at the outdoor education center. This activity is based on the game "Carbon Adventures: A game to teach the carbon cycle," which can be found through the Arizona State University's GK-12 project: http://gk12.asu.edu/node/45.

Key Concepts

- Describe what carbon is.
- Describe the difference between organic and inorganic carbon.
- Identify carbon pools.
- Identify the different forms carbon takes throughout the carbon cycle.
- Describe pathways in which carbon can move throughout the environment.
- Describe how humans influence the carbon cycle.

Grade Level: 6^{th} – 8^{th}

Materials: Instructions sheet, carbon cycle cards, carbon cycle pool sheets, carbon cycle "maps," pencils, Periodic Table, colored pencils.

Time: 40 minutes – 1 hour

Introduction

Carbon is an element that is essential for all life; all living organisms are composed of carbon. (Show the Periodic Table of Elements and where carbon is located.) Carbon atoms take many forms as they move through the environment. Carbon can be found as an organic molecule (molecules that are of biological origin- wood, leaves, sugars, starches) or an inorganic molecule (molecules that are not of biological origin - carbon dioxide, bicarbonate). As carbon moves from one location, or "pool," to another, it changes form through different processes. The following game uses eight major carbon pools: Vegetation, Animals, Bacteria and Fungi, Litter and Waste, Fossil Fuels, Industry and Vehicles, Atmosphere, and Ocean. This game will focus on how carbon moves on land, but similar processes happen in the ocean as well. Nutrient cycles, like the carbon cycle, do not occur in a fixed pattern. A single atom of carbon may never visit some of the carbon pools.

After introducing students to all of the carbon pools and the forms that carbon will take in each, emphasize human alterations of the carbon cycle during recent history. The largest disturbance to the global carbon cycle began in the Industrial Revolution with large-scale use of fossil fuels for energy. By removing fossil fuels from below the ground-surface, humans reintroduce carbon that has been out of circulation for millions of years back into to the global carbon cycle. When fossil fuels are burned to produce energy, the carbon in them is converted to carbon dioxide. This carbon dioxide enters the atmosphere, where it has been accumulating since the Industrial Revolution. However, the level of carbon dioxide in the atmosphere is not as high as we would expect it to be. Scientists have been looking for the "missing carbon," and have discovered that most of the missing carbon is taken up by forests in the northern hemisphere and dissolved into the oceans. These places are called carbon sinks.

Procedure

1) Create the eight carbon cycle pool sheets. You can draw a picture to represent the various carbon pools, or print pictures representing vegetation, atmosphere, bacteria and fungi, litter and waste, fossil fuels, industry and vehicles, animals, and the ocean. Print the associated cards for those stations. Print a carbon cycle map sheet for each student.

2) Set the eight carbon cycle pool sheets at various locations throughout the room, or outside in an open area.

3) After a background discussion with the students about the carbon cycle, explain that each student will get a carbon cycle map sheet. As each student makes his/ her journey though the carbon cycle, they need to mark the map using arrows.

4) Divide students up into 8 teams (one for each pool).

5) At each station, have students draw a card and follow instructions on it.

6) Have students go through the game until their maps are full of arrows. It is fine if students repeat stations or don't go to all stations. That is how the carbon cycle works.

7) At the end of the round, discuss the carbon cycle:
   - What is carbon?
   - Where is carbon found?
   - How does carbon move from one pool to another (photosynthesis, evaporation, burning fossil fuels)?
   - What are some of the different forms carbon can take in the carbon cycle?
   - What is the difference between organic and inorganic carbon?
   - Does a carbon molecule always take the same path, or visit every pool?

Round 2 – Without Human Influence

1) Have the students remove all the game cards where humans alter the environment. These are the cards printed in blue.

2) Have students go through the game again with a new map sheet or a colored pencil to distinguish their new journey on their old sheet.

Wrap- up

After playing the two rounds, and discussing the students' carbon pathway maps, have the students look at their maps and describe the carbon pools that they visited. Carbon can be stored in pools, or sinks, for millions of years. The actual number of carbon pools in the carbon cycle is debated. Most carbon cycle explanations include the atmosphere, the soil, oceans, and fossil fuels. One carbon pool that was not discussed during this game is the earth's interior: carbon from the earth's mantle is released through volcanic activity. Discuss reasons why the carbon cycle is so complex and can be challenging to understand.

Discussion Questions

- Without human influences, how did the carbon cycle change?
- Which carbon pools are most influenced by human activity?
- How is this like the real world? How is it different?
- How long do some of these processes really take?
- What can we do to lessen our impact on the carbon cycle?
- Why should we change anything?
- Which parts of the carbon cycle do you personally influence? How?

Animals

You are carbon that was unable to be digested by the animal that ate you. You have been excreted as waste. Go to the **LITTER AND WASTE** pool.	You are carbon that was eaten by an animal and now has become part of that animal's body. Stay at the **ANIMAL** pool (circle it on your map) and pick up another card to continue your journey.	You are carbon in the body of an animal and you die. Your body is being decomposed by beetles, worms, and bacteria. Go to the **LITTER AND WASTE** pool.
You are carbon in the form of sugar and you go through respiration (the process where nutrients are converted into useful energy in a cell), and provide the animal with energy. During this chemical process, Carbon Dioxide is a by-product. Go to the **ATMOSPHERE** as Carbon Dioxide (CO2).		

Oceans

You are carbon in the form of bicarbonate that is dissolved in the seawater. You are then evaporated, and released into the atmosphere as $CO2$. Go to the **ATMOSPHERE** pool.	You are carbon from decomposing marine life. You are circulated into the deep ocean, where you are stored for hundreds of years. The deep ocean holds 65% of the world's carbon. Eventually, you are evaporated and released into the atmosphere as $CO2$. Go to the **ATMOSPHERE** pool.	Tiny ocean organisms, called phytoplankton, use carbon to make energy through a process called photosynthesis. The phytoplankton are then eaten by larger organisms. Go to the **ANIMAL** pool.
You are carbon in the form of bicarbonate that is dissolved in the seawater. You are then evaporated, and released into the atmosphere as $CO2$. Go to the **ATMOSPHERE** pool.	You are carbon from decomposing marine life. You are circulated into the deep ocean, where you are stored for hundreds of years. The deep ocean holds 65% of the world's carbon. Eventually, you are evaporated and released into the atmosphere as $CO2$. Go to the **ATMOSPHERE** pool.	Tiny ocean organisms, called phytoplankton, use carbon to make energy through a process called photosynthesis. The phytoplankton are then eaten by larger organisms. Go to the **ANIMAL** pool.

Vegetation

You have been taken out of the atmosphere by a plant as it used the Sun's energy to make the nutrition it needs (a process called photosynthesis). You are now one of the building blocks that make up a plant. As more carbon dioxide is added to our atmosphere, plants will be able to grow faster. Plants also release carbon back to the atmosphere by respiration. You have now been released into the **ATMOSPHERE** pool.	You are now sugars in the leaf that have been eaten by an animal, and used for energy. Go to the **ANIMAL** pool.	You are carbon in the form of sugars give off by the roots to feed bacteria and fungi to provide nutrients. Go to the **BACTERIA and FUNGI** pool.
We are afraid to say that the plant you were in has died. The good news is that, you are now a part of the soil called detritus, which is decomposing plants and animals. Soil is made of organic parts such as dead and living plants and soil organisms. Soil is also made of inorganic parts such as sand, silt, and clay. Soils store about 3% of Earth's carbon. As bacteria and fungi breakdown the detritus, carbon is sent into the atmosphere. Go to the **BACTERIA and FUNGI** pool.	You are carbon that has been released by burning wood in a campfire. Go to the **ATMOSPHERE** as CO2.	You are sugars that are being stored in the plant. Stay at **VEGETATION** (circle it on your map) and pick up another card to continue your journey.

Atmosphere

You are carbon that was diffused from the atmosphere and enters the ocean. Go to the **OCEAN** pool.	You are carbon in the form of CO2. You stay in the **ATMOSPHERE** (circle it on your map) and pick up another card to continue your journey.	You are carbon in the form of CO2, found in the atmosphere. You are taken up by a plant for photosynthesis- a process that makes energy for the plant. Go to the **VEGETATION** pool.
You are carbon that was diffused from the atmosphere and enters the ocean. Go to the **OCEAN** pool.	You are carbon in the form of CO2. You stay in the **ATMOSPHERE** (circle it on your map) and pick up another card to continue your journey.	You are carbon in the form of CO2, found in the atmosphere. You are taken up by a plant for photosynthesis- a process that makes energy for the plant. Go to the **VEGETATION** pool.

Bacteria and Fungi

You are carbon found in the body of bacteria. You die, and go to the **LITTER AND WASTE** pool.	You are carbon found in the body of a fungus. You continue to grow. Stay in the **BACTERIA AND FUNGI** pool (circle it on your map) and pick up another card to continue your journey.	Bacteria and Fungi break down the detritus in and on the soil. During this process, Carbon is released into the atmosphere. Go to the **ATMOSPHERE** pool.
You are carbon found in the body of bacteria. You die, and go to the **LITTER AND WASTE** pool.	You are carbon found in the body of a fungus. You continue to grow. Stay in the **BACTERIA AND FUNGI** pool (circle it on your map) and pick up another card to continue your journey.	Bacteria and Fungi break down the detritus in and on the soil. During this process, Carbon is released into the atmosphere. Go to the **ATMOSPHERE** pool.

Litter and Waste

You are carbon in the form of organic material that cannot be broken down by bacteria or fungi. Stay in the **LITTER AND WASTE** pool (circle it on your map) and pick up another card to continue your journey.	You are carbon in the form of organic material. You are broken down by bacteria and fungi. Go to the **BACTERIA AND FUNGI** pool.	You are carbon that is found in dead plants and animals. Eventually, you are covered by soil and are buried. Millions of years of pressure converts you into a type of fossil fuel. Go to the **FOSSIL FUEL** pool.
You are carbon in the form of organic material that cannot be broken down by bacteria or fungi. Stay in the **LITTER AND WASTE** pool (circle it on your map) and pick up another card to continue your journey.	You are carbon in the form of organic material. You are broken down by bacteria and fungi. Go to the **BACTERIA AND FUNGI** pool.	You are carbon that is found in dead plants and animals. Eventually, you are covered by soil and are buried. Millions of years of pressure converts you into a type of fossil fuel. Go to the **FOSSIL FUEL** pool.

Industry and Vehicles

You are carbon found in fossil fuels, such as gasoline. You are burned in a car. You now go to the **ATMOSPHERE** pool as Carbon Dioxide.	You are carbon found in fossil fuels, such as coal. You are burned in a coal-fired power plant. You now go to the **ATMOSPHERE** pool as Carbon Dioxide.	
You are carbon found in fossil fuels, such as gasoline. You are burned in a car. You now go to the **ATMOSPHERE** pool as Carbon Dioxide.	You are carbon found in fossil fuels, such as coal. You are burned in a coal-fired power plant. You now go to the **ATMOSPHERE** pool as Carbon Dioxide.	

Fossil Fuels

You are carbon found in coal in a West Virginia mountain. Through the mountain top removal process, you are removed from the earth and transported to a coal-burning power plant. Go to the INDUSTRY AND VEHICLE pool.	You are carbon in the form of fossil fuels. It will be many years until you are discovered and extracted from the earth. Stay in the FOSSIL FUEL pool (circle it on your map) and pick up another card to continue your journey.	You are carbon in the form of oil located off the coast. For many years the area has been protected, and off-shore drilling was illegal. Recently, the law was overturned and now drilling is allowed. Go to the INDUSTRY AND VEHICLE pool.
You are carbon found in the form of oil located off the coast. The area where you are located is under federal protection- no drilling is allowed. Stay in the FOSSIL FUEL pool (circle it on your map) and pick up another card to continue your journey.	You are carbon found in the form of natural gas. You are extracted and used to heat people's homes, and for gas stoves. Go to the INDUSTRY AND VEHICLE pool.	

City Planners

Educator Summary

Many people would love the opportunity to live close to a beautiful natural area like the Great Smoky Mountains National Park. Unfortunately, as human population increases near these areas, our impact on them increases as well. In this activity, students are given the opportunity to design their own community on the border of the Smokies. This activity was inspired by Project Wet's "Sum of the Parts" activity, in which students learn about point source and non-point source pollution of a watershed. In this game, students are given an ecosystem, allowed to build a community there, and must determine where their greenhouse gas and other air pollutants come from. At the end of the activity they can redesign their community to decrease their impact.

Communities built immediately on the edge of the park heavily impact the Great Smoky Mountains National Park. The most heavily used entrance to the park is on the Tennessee side near Gatlinburg. Sevier County, which includes the communities of Gatlinburg and Pigeon Forge, has a population of over 71,000 people, but nearly 12 million tourists stay in or travel through the county each year. With amusement parks, go-kart tracks, pancake houses, and more, these two cities are destinations unto themselves. The students are asked to consider the sources of air pollution, like ozone and particulate matter, the sources of greenhouse gases, and the likely effects of these emissions. This activity is written to help students consider the impacts of their choices on all scales, from local to global.

Key Concepts

- Students will identify the sources of greenhouse gases and air pollution in communities.
- Students will identify methods to reduce greenhouse gas emissions.
- Students will make decisions about the importance of certain fossil fuel burning activities.

Grade Level: 6^{th} – 8^{th}

Materials: Large map of the national park, white board, dry erase markers. Each small group will need a large piece of butcher paper with park boundary and natural features marked on it, markers or crayons, tape, scrap paper.

Time: 45 minutes

Introduction

The Great Smoky Mountains National Park is a protected area of land. People are not allowed to build buildings or cut down trees within the park boundary. When you walk across the border though, you enter private lands. While property lines are important to people, do animals, plants, air, and water honor these boundaries? In this activity, groups of students will be landowners with property just outside Great Smoky Mountains National Park. Each group is in charge of planning a new community for its piece of land. As a group, they must decide what they would like to include in their community, what they must include in their community, and the layout of their proposed town.

Procedure

1) Prepare the "land" for the small groups. On a large piece of butcher paper, draw the park boundary. The rest of the paper should have natural features marked on it (mountains or hills, water, forested areas).

2) Ask the class to list the things that MUST be in a town such as roads, houses, businesses, electricity, water, sewage, and garbage, in order to maintain the standard of living that currently exists in most of the United States. The class must agree on what things must be included in each community.

3) Divide the class into small groups of 4 or 5 students.

4) Assign each group to one of the butcher paper landscapes.

5) As a group, the students will plan their community, including all of the things listed in Step 2 and any other things they wants to include to make their community more attractive to potential home owners or business people. Make sure to check on the communities and remind them about roads and houses.

6) Come back together as a class, and have each group present its planned community.

7) Ask the class to think about their communities' impact on their sites. What are potential sources of pollution? Remember to think about water, air, garbage, foot traffic, cars, electricity production, noise, street lights, etc.

8) Ask the students to consider their impact on the air quality in particular. Where in their community are fossil fuels being burned? Almost all of the electricity produced for

communities near the Smoky Mountains comes from burning coal. Rivers in this area are not large enough to support hydro-electric power, but wind and solar power are options that could supplement coal, though the forested landscape makes both solar and wind electricity production less efficient.

9) Where are greenhouse gases being produced? Are all of the sources for the pollution mentioned above also producing greenhouse gases? What will be the impact of greenhouse gases on this community? While the community itself might not feel the impacts of their particular greenhouse gas contribution, the gases building up in the atmosphere will have a worldwide impact.

10) Small groups will now mark on their maps where different kinds of pollution come from and discuss the impacts on the nearby national park. Finally, come together and discuss these additions.

Wrap-Up

1) Tape the communities up around the national park map, demonstrating where these communities would exist.

2) Will the location of the community (east, west, near Fontana Lake, etc) matter to the degree in which they will impact the park? Most weather comes from the Tennessee side of the park, blowing air pollution into the park. On the North Carolina side of the park, there are large national forests that make development difficult but help lessen human impact right next to the park.

3) Pick one community to move far away from the park. Can this community still impact the park? How? How will moving this community change the impact of its greenhouse gas emissions?

Air pollution in particular can travel long distances and get ‘stuck’ in the Smokies. The park has one of the worst air pollution problems in the national park system. Some days in the summer, the air quality is worse than in Los Angeles. The mountains act like a wall for weather patterns traveling in from the west. As the weather hits the 6,000 foot peaks of the Smokies, it is effectively trapped. Clouds drop precipitation as they are forced up over the mountains (See “The Orographic Effect” activity earlier in this resource guide). Pollution such as ground-level ozone gets caught, resulting in bad air quality alert days in the high mountains to the point that people are advised to avoid hiking.

While air pollution, such as ground-level ozone, particulate matter, and sulfur oxides are local or regional problems, greenhouse gases, like carbon dioxide, are a different story. The greenhouse gases that any particular community contributes to the atmosphere will have planet-wide effects. As the greenhouse gases increase, more heat will be trapped in the atmosphere, leading to increased average global temperatures. The air pollution created in the United States will have the heaviest impact on the U.S., but the greenhouse gases emitted in the United States will impact the world.

Discussion Questions

- Is there anything you would like to change in your community to lessen your impact on the National Park?
- How could you lessen your impact on the planet?
- Will this change the number of people who will want to live here? Why or why not?
- Are any of these changes likely to make things cost more?
- What will that mean to your community?

Variation – For High School Students

After completing the above steps, move all of the communities away from the park into the following areas: (A) along the Georgia/South Carolina border, (B) into the flat piedmont region of Georgia or Alabama, (C) into the coal region of West Virginia, and (D) into the rolling hills of Kentucky. Now that all of the communities are farther away from the park, discuss how these communities impact the Smokies. The students may decide there is no longer an impact from all of these communities. Tell the students that the new location of their community means that there are different opportunities for development. In community (A) there is now a paper mill. The river that forms the border between the two states is the perfect place for industry. Ask the group to consider the impact on their community (jobs, smell, increased revenue for the city and county, more people) and the impact on the natural landscape (water pollution, both chemical and thermal, air pollution, aesthetics of the building, the traffic from trucks, etc). Assign each group to consider a new industry in their community: (B) – pine plantation, (C) – surface coal mine (mountain top removal), (D) – automobile assembly plant.

Each group should consider the impacts of the above changes on their community. Ask them to think about rebuilding their community now that the landscape has changed. What would they change, what would stay the same? How does this new industry change the impact the town has on the surrounding natural environment? How does it impact far away natural areas like the Smokies? How does it impact the global environment?

Check This Out!

- Robert Krulwich and National Public Radio have produced a five-part animated video that explains the role of carbon in climate change in a clear and engaging way. http://www.npr.org/news/specials/climate/video/

-The United States Environmental Protection Agency detailed information about carbon and climate change. Start here http://www.epa.gov/climatechange/emissions/co2.html to explore carbon dioxide in the environment.

-Another carbon cycle game worth visiting: http://www.windows2universe.org/earth/climate/carbon_cycle.html

Sources

Diving In – The Atmosphere

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Carbon Cycle Pathways

This activity is based on the game "Carbon Adventures: a game to teach the carbon cycle." This can be found through the Arizona State University's GK-12 project: http://gk12.asu.edu/node/45 Used with permission.

City Planners

"Dragonfly Pond". Project Wild: Aquatic Education Activity Guide. Bethesda, MD: Council for Environmental Education, 1992.

Biodiversity and the Dependence of Organisms on their Environments

Biodiversity and interdependence are common themes in environmental education programs around the country. Helping students understand the importance of all the parts of the living community is the mission of many of these outdoor classrooms. As the impact of climate change on our planet increases, these complex relationships will change, some in ways that are difficult to predict.

Following is a discussion on how to adapt a popular biodiversity activity to help discuss the impact of climate change on organisms and habitats. The Black Bear Carrying Capacity Game is an activity used at Great Smoky Mountains Institute at Tremont to illustrate the natural carrying capacity of black bears in the park and how climate change could impact this.

It may be simple to understand how increased temperatures can alter habitats and food sources. However, how do we know that our world is changing? It is important to observe and document changes in the local environment. The phenology lesson is a series of activities designed to help younger students notice seasonal changes and gain an appreciation of the reasons for those changes. For older students, this lesson will delve into the complex relationships between species and the changing climate.

Web of Life Climate Change Variation

This common environmental education activity from Project Learning Tree is a great tool to teach about the interconnectedness of life. Students are asked to represent different parts of the ecosystem. As they discuss how one organism is connected to another, they pass a ball of yarn forming a web. After establishing your group web, choose an example of the impact of climate change in your local ecosystem. Use this example to show the rippling effect throughout your web community. Take a look at the Project Learning Tree curriculum guide for the full write up on the Web of Life activity.

Focus On the Great Smoky Mountains

The parts of the web used in the Smokies include streams, which are home to brook trout. One example of the impact of climate change on this web is that water temperatures in streams will increase as air temperatures increase. These warmer streams impact cold-water fish like brook trout. These native trout are already facing competition from the invasive brown trout. Warmer streams might be the last straw for the brook trout in the Smokies. The effect of warmer streams won't be limited to the brook trout, however. Aquatic insects and salamanders are examples of two other organisms commonly included in the Tremont Web of Life that are affected by these changes.

Wrap-Up

Climate change will impact different species in different ways. Some species will be able to adjust and move to a new, more hospitable environment as temperatures and precipitation levels change. Others won't be able to make that change. Some species have a variety of connections in the web with a wide range of food sources and a wide range of habitats, but others are limited in their food choices and habitats. What does climate change mean for them?

Discussion Questions

- How is this activity accurate to a real environment? How is it not?
- Are there any other ways to set up these same species in a different web?
- Would that change the impact as one species is eliminated or impacted?
- What does that mean for the impact of climate change?
- How do people fit into this web?
- What does this mean for us as climate change happens?
- What if we include our crops into the food web?

Black Bear Carrying Capacity Game

Educator Summary

Black bears in the Smoky Mountains have become a symbol of the wildness of the park. The Great Smoky Mountains National Park is the most visited park in the country with nearly 10 million visitors annually. All of these people and all of their cars have an impact on all parts of the ecosystem. We have chosen to focus this activity on the bears because they are easily identifiable and relatable animals for most of the visiting students. Students have heard about the bears, know they are predators and are "scary," but, many times, that is it. We hope that using an interactive game to introduce students to the struggle that bears face to survive will allow students to understand the complex relationships between all of the living things within this park.

This lesson plan can be used as is or as a guideline for adapting your own carrying capacity activity to help address the complex issue of climate change.

Key Concepts

- Students will explain the concept of carrying capacity.
- Students will identify how a changing climate might impact a species' carrying capacity.

Grade Level: 6th – 8th grades

Time: 45 – 60 minutes

Materials: Large open area, preferably with wooded area around it, cups to designate "dens," labeled food cards, blindfold, whiteboard, markers for graphing population changes.

The table below describes how food cards should be color coded and labeled with their points.

Green (Plants)		**Purple (Berries)**		**Orange (Nuts)**		**Red (Meat)**		**Yellow (Insects)**	
Number of cards	Point value	Number of cards	Point value	Number of cards	Point value	Number of cards	Point value	Number of cards	Point value
15	10	15	10	15	10	15	10	15	10
5	20	5	20	5	20	5	20	5	20

Introduction

The black bear once roamed across most of North America. Deforestation has restricted the range of black bears to the remaining wooded areas. The 800 square miles of protected forest in the Great Smoky Mountains National Park offers a refuge for the black bear. Bears range across all elevations in the park, and as of 2006, the population was found to be approximately 1500 bears (NPS).

A carrying capacity is the number of individuals of a particular species that a given area is able to support. This limit is often closely related to the amount of food available. In this game, students will get a glimpse of what it's like to be a bear competing for limited resources.

Procedure

1) Make 100 food cards as follows: twenty 2 x 2” cards each of the five colors - green, purple, orange, red, and yellow. For each set of twenty cards, write 10 on 15 of them and 20 on the remaining 5.

2) Scatter the food cards over a 50 x 50’ area. Do not tell the students what the color, initials, and numbers on the cards represent just yet. Tell them only that the pieces of paper are different kinds of bear food. Since bears are omnivores (like people), they can eat a wide assortment of foods, so the students should gather different colors to represent this variety of food.

3) Have students go to a place they designate as their dens and mark them with their cups.

4) Have students collect cards, keeping in mind that bears do not run after their food and that they must take the food back to their dens one piece at a time. No bear can steal food from another bear’s den.

5) When all the food has been collected, the students should bring their cards and sit in a circle.

6) Ask the students about how it felt to be competing for their food. Explain that the numbers on each card represent the amount of energy available from that food source in a given area of bear habitat:
    a. Green cards are grasses and plant leaves.
    b. Purple cards are berries and other fruit.
    c. Orange cards are acorns and other nuts.
    d. Red cards are animal matter.
    e. Yellow cards are insects.

7) Round 1 Discussion: Have each student add up the points on his or her own cards, and explain that it takes 80 pounds per 10-day period to keep a bear alive. If a bear does not have 80 pounds of food, what happens? (The bear would starve, migrate out of the area, or kill another bear and take over its territory.) A given bear habitat can only support a limited number of bears. How many bears in this activity could have survived? The number of bears an area can support is called the carrying capacity. Have students calculate the carrying capacity by dividing the total number of points obtained by the group collectively by 80 (the number of pounds to keep a bear alive for 10 days). At end of each round, ask students to calculate the carrying capacity,

which will change as the conditions of the game change. Keep track of this information so it can all be graphed at the end of the activity.

8) Round 2: Play the game again, but explain to the group that not all bears are equally prepared to survive. Designate some students as having cubs. These students will have to collect 120 pounds of food to feed themselves and their cubs.

9) Round 3: Blindfold a student. This bear tried to kill a raccoon, was scratched in the eyes, and is now blind.

10) Round 4: The previous rounds focused on how individual bears might be limited in how much food they can collect. There are other factors that can limit how much food is available. Remove most of the orange cards and play the round again. This was a low mast year for oak trees, meaning that the oak trees did not produce many acorns.

11) Round 5: Remove 50% of all cards. Due to an unseasonably hot summer with little rain, plants and animals are struggling to survive. There will be fewer berries, acorns, insects, animals, and grass. What will happen when a bear population has such a difficult year or two?

12) Round 6: Destroy some of the "dens." Due to a changing climate, flooding has become an issue in the spring. During the summer, drought makes forest fires a larger threat. These issues can limit the number of available den sites for winter. What will happen to the bears that no longer have dens?

Wrap-Up

Gather the students to graph the information. Graph the first round as a group, comparing the carrying capacity line in one color with the actual population in another color. Now ask the students to work in small groups to graph other rounds. Ask each group to present their findings about the differences between carrying capacity and actual population.

Discussion Questions

- What do bears do to meet their requirements for food, water, and shelter?
- Do other species, besides bears, have a carrying capacity in a specific habitat?
- What are some examples of ways that people impact carrying capacity?
- Do we ever increase an area's carrying capacity for certain species?

- How will climate change affect the bear populations' carrying capacity in the park? What about the populations of deer, trees, birds, and fish?
- Is there a carrying capacity for people in this park, this country, or the world?

Phenology

Educator Summary

Phenology is the study of when seasonal changes occur. When looking at phenological data, some species show a gradual shift in their seasonal timing as the global climate changes, while other species do not. This lesson is designed to help put students in touch with the changes that they see around them. While people may notice robins in the spring, most do not mark down the date year to year. For younger students, making note of changes is an important step in understanding the complicated issue of a changing climate. They will also explore how living things adapt to their environments and are interdependent with other organisms. For older or more advanced students, a connection can be made between the seasonal changes and the changing climate, along with a deeper understanding of the complex relationships that exist between species and their environments.

Outdoor education centers are in ideal situations to track local seasonal changes. Having dedicated people outside every day allows us to notice and record when certain events are happening on an annual basis. With a little bit of planning, phenology can become a part of the curriculum of any outdoor education facility. The Great Smoky Mountains Institute at Tremont has been collecting phenological data since 1985 and is trying to help visiting schools take this activity back to the classroom. If your center or classroom doesn't have a database of phenological data, use Tremont's information to get started, and make the switch to your own species of interest as the data builds.

This lesson is designed for the outdoor education center with year-long implementation at the school. It is written as four small activities within one cohesive lesson plan. The activities can be pulled out and used independently as needed.

Activity 1: What is Phenology?

Key Concepts

-Students will be able to define phenology.
-Students will describe seasonal changes, and factors that might affect these changes.
-Students will create a phenology list.

Grade Level: 6th – 8th grade

Time: 10 minutes

Materials: White board, markers, paper, pencils

Introduction: What is Phenology?

Phenology is a branch of science dealing with the relationships between climate and periodic biological phenomena such as bird migration or plant flowering. Ask students, how they know when winter changes to spring without looking at a calendar. The answer doesn't have to be from clues in nature; answers could include that stores start putting out Easter candy, or that swimsuits are for sale.

Procedure

1) Prepare a white board with four columns labeled with the four seasons.

2) Divide the students into four groups and assign each group to one of the seasons.

3) Ask them to make a list of the signs of that season. What do they look for each year that signifies a new season is coming?

4) When they have completed their list, write it up on the board in their column. Ask students to try to put a general date or month when the event happened or usually happens.

5) When all four groups are done, review the lists and try and think of anything that might be missing.

6) Ask the class to group the answers into categories as they see fit. They might, for instance, suggest plant signs, animal signs, calendar events, and human activities.

Wrap-Up

Many of these things are a part of phenology. The first migratory bird, the first tulip, and the first red maple leaf are some of the phenological signs that show changing seasons.

Discussion Questions

-What might cause seasonal changes to occur earlier or later than average? (Temperature, rainfall)
-The dates of these changes might be pretty much the same year to year. What does that mean? (They are dependent on a trigger like the length of day instead of temperature.)

Activity 2: Phenology Scavenger Hunt

Key Concepts

- Students will learn about the phenology project happening at GSMIT.
- Students will be able to explain why recording phenology is important.
- Students will practice making observations for a phenology list.

Grade Level: 6^{th}- 8^{th} with High School Variation

Time: 30-60 minutes

Materials: Copies of current phenology list, large phenology map, Scavenger Hunt Sheets and pencils, Field ID books, binoculars (if available).

Introduction

Tremont staff and visitors have been keeping track of the phenology of our home for years. Each season we put out a new list to record when and where we see the first signs of each season. Being observant is important when working on phenology. In order for the information to be accurate, seasonal changes need to be noticed and recorded as soon as they occur within the area of study. Pass around copies of the phenology list for the previous season. Why do we keep track of this? We think it's interesting, it tells us something about our changing climate, this is a good way to keep track of our observations, and we're competitive! It's like a big scavenger hunt. When we or our visitors are the first to find something on the list, we mark it down and put it on the map.

Procedure

1) Have the students work in pairs or small groups.

2) Pass out copies of a current phenology list or the Seasonal Phenology Scavenger Hunt.

3) Students will be exploring the GSMIT campus in their small groups to find items on the list. It doesn't matter if they have been spotted already this season.

4) Ask the students to pick two or three things off the Seasonal Phenology Scavenger Hunt. These are the items they are going to search for. Have them look up the items in the appropriate field ID book.

5) Stress the boundaries of the search area and ask the other adults in the group to search with the students. NOTE: This can also be done as a group on a short hike, the goal being for the group to spot as many things on the list as possible.

6) Ask students to record where they find items on the list.

7) After each group has had the chance to look for several items, gather the group together.

8) Have each group fill out sample icons to place on the large phenology map (These will not stay up after the class is over unless it is a first sighting.)

Wrap-Up

In this activity, students are given a particular time to be observant and only a few items to find. Back at school, with friends, homework, sports, teachers, and all the parts of a regular day, it can be difficult to remember to notice the trees, flowers, and insects. It's important to slow down, look, and take notes. Ask the teams to map another team's phenology information. Based on the notes alone, another group should be able to place the icon in the proper place. Taking clear notes is important in marking the location of these organisms.

This practice phenology mapping activity will also help the group to think about landmarks and important features that need to be included on their school map.

Variation – High School

Before doing the Scavenger Hunt, take a look at the data GSMIT has collected thus far in more detail. Each small group of students will get one of the Species of Interest background sheets. The groups will prepare a short presentation about their species, including information addressing the impact of climate change on this species.

Spring Phenology Scavenger Hunt

Observation	Location
Monarch Butterfly	
Silver-spotted skipper	
Macroinvertebrates emerging (or you spotted an exoskeleton)	
Yellow lady slipper in bloom	
Dutchman's pipe in bloom	
Yellow stargrass in bloom	
Sweetgum tree blooming	
Rosebay rhododendron in bloom	
Flame azalea in bloom	
Galax in bloom	
Black/raspberries in bloom	
Cicada buzzing	
Dwarf Crested Iris blooming	
Yellow Trillium	
Leaf buds opening on trees	
Leaves on trees greater than 2 inches long	
Air temperature above 60 degrees F	
Toads	
New growth on Hemlock trees	

Fall Phenology Scavenger Hunt

Observation	Location
Iron weed blooming	
Cardinal flower blooming	
Sourwood leaves turning red	
Dogwood berries red	
Fall yellowthroat migrating	
Closed gentian in bloom	
Sweet birch leaves turning	
Oak leaves turning	
Red maple leaves turn red	
Witch hazel in bloom	
Toothwort leaves out	
First junco returns	
First snow flakes	

Signs of Spring

Observation	Earliest		Average		Current Date	Initials	Location
Monarch Butterfly	April	1	April	19			
Fawn	April	1	May	13			
Silver-spotted skipper	March	27	April	20			
Whiporwill singing	April	7	April	21			
Yellow Lady slipper in bloom	April	17	April	23			
Dutchman's pipe in bloom	April	17	May	1			
Yellow Stargrass in bloom	April	3	April	26			
Pink Lady Slipper in bloom	April	21	May	3			
Rosebay Rhododendron in bloom	April	23	May	30			
Flame Azalea in bloom	April	24	May	2			
Galax in bloom	April	23	May	6			
Black/Raspberries in bloom	April	4	May	2			
Cicada Buzzing	May	2	May	24			

These are some of the signs of spring you can observe in Walker Valley. Watch for these events and record the first day they are seen in Walker Valley.

Signs of Fall

Observation	Earliest		Average		Current Date	Initials	Location
Iron Weed Blooming	July	23	Aug	7			
Cardinal Flower Blooming	July	3	July	27			
Sourwood leaves turning red	Aug	24	Sept	11			
Dogwood berries red	Aug	5	Sept	1			
Fall Yellowthroat migrating	Sept	22	Sept	28			
Closed Gentian in bloom	Sept	21	Sept	28			
First hard frost	Oct	2	Oct	22			
Sweet birch leaves turning	Oct	6	Oct	14			
Oak leaved turning	Oct	12	Oct	19			
Red maple leaves turn red	Sept	30	Oct	6			
Asian ladybugs invade homes	Sept	8	Oct	18			
Witch hazel in bloom	Oct	18	Nov	1			
Toothwort leaves out	Oct	15	Oct	25			
First night without Katydid calls	Oct	13	Oct	26			
First snow flakes	Oct	23	Nov	22			

These are some of the signs of fall you can observe in Walker Valley. Watch for these events and record the first day they are seen in Walker Valley.

Winter Wonders

Observation	Earliest		Average		Current Date	Initials	Location
Dandelion in bloom	Jan	1	Jan	22			
Wood frog eggs	Jan	4	Jan	30			
Violets (blue/purple) in bloom	Jan	20	Feb	25			
Bat flying	Jan	4	Feb	13			
Hepatica in bloom	Jan	30	March	8			
Spring peeper	Feb	1	March	4			
Red-winged blackbird	Feb	9	Feb	23			
Chipmunk	Feb	2	March	7			
Red Maple	Feb	12	March	4			
Spring beauty in bloom	Feb	15	March	9			
Water snake	Jan	29	March	22			

These are some of the signs of winter you can observe in Walker Valley. Watch for these events and record the first day they are seen in Walker Valley.

Wood Frog

Rana sylvatica LeConte

Wood Frogs are one of the earliest amphibians to emerge in the spring. The frogs spend the winter frozen in their hiding places in the woods. When the temperature gets above 40 degrees, wood frogs make their way to temporary pools to mate and lay their eggs. Listen for the quaking call of the male wood frog at dusk and dawn on a warm day in January. Check in the drainage ditch behind the dorm late winter and early spring to see the huge masses of eggs or wiggly tadpoles.

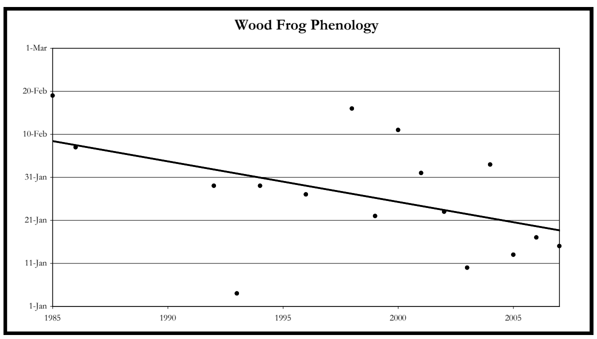
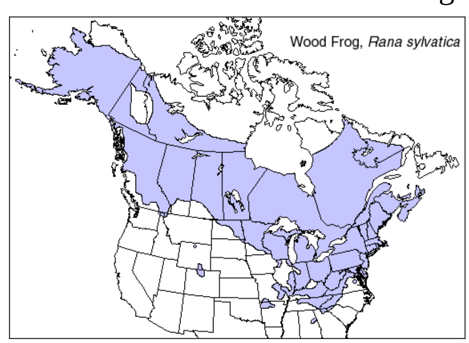


Figure 1. These are the dates on which wood frogs were first observed mating, calling, or laying eggs in Walker Valley. Wood frogs have been emerging about 20 days earlier since 1985.

DESCRIPTION

Key Characteristics: Small tan to reddish brown frog. Dark mask from lower half of eye back to front leg. Back sometimes has a few black dots. Legs sometimes have dark bands. Breeding male is smaller than female.



Wood frog range map produced by the U.S. Geological Survey

NATURAL HISTORY

Habitat: Wood frogs are found in or near moist wooded areas, often far from open water.

Breeding: Large breeding populations appear after the first warm rains of late winter. Females lay masses of 300-900 eggs, which will hatch in 10 to 14 days. Tadpoles will have metamorphosed by April or May.

Diet: Invertebrates

CONSERVATION BIOLOGY

While the wood frog is not endangered or threatened, many parts of its range are becoming fragmented by urbanization. Roads and the cutting of forest cover in particular result in population reduction or even removal. Wood frogs are dependent on multiple habitats from wetlands, to damp lowland forests, to dryer upland forests. The wetlands, in particular are facing reduction or degradation in much of the United States.

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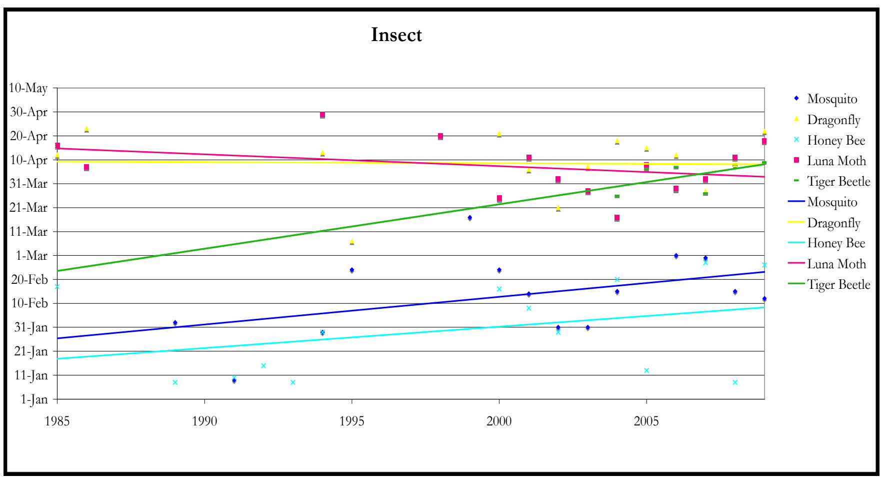


Figure 2. Wood frog adults eat insects. Tadpoles eat aquatic insects and algae. The above graph shows the first date several species of adult insects were spotted in Walker Valley.

Wood Frog

Questions for the students

- What does Figure 2 mean for the wood frogs?
- Will there be food available for the mating adults in early spring?
- How about for the new adults as they emerge in April?
- Will the availability of food have an impact on the wood frog population?
- Based on what you now know about wood frogs, what is going to be the limiting factor on wood frog population?
- What will potentially warmer winter temperatures mean?
- How about a change in precipitation patterns?
- What are some of the possibilities if there is more or less rain?
- What could happen if there are warmer or cooler temperatures in winter or summer?

Wood Frog Teacher Notes

Wood frog adults eat a wide variety of forest insects. The insects on the graph may or may not be important insects for wood frogs. Help students to think critically about the short-comings of comparing these two graphs. Consider the following questions:

- Is this enough information to make conclusions?
- Are there other sorts of data that might be more important for this species?
- Are these pertinent insect species to be examining? Why or why not?

Concerns for wood frogs include: forest fragmentation, wetland loss, and loss of forest cover. Warmer winter temperatures may not negatively impact these frogs. Changes in precipitation, particularly drier winters and springs, would result in a loss of breeding pools.

Tremont staff members have become more involved with this project throughout the years. This involvement has inspired both staff and guests alike to search more thoroughly for certain species. This increased enthusiasm and participation may have impacted the data. This is an important note for the students to consider. In order to understand the data, the students must understand the methods used for data collection, including the shortcomings of such methods.

The local results for climate change are complex and not fully understood. Help students think critically about the needs of this species and what a wide range of potential changes in their environment might mean. Consider warming temperatures throughout their range and changes in precipitation, both in amount and in timing.

Black-throated Green Warbler

Dendroica virens Gmelin

Photo by John Harrison

Black-throated green warblers, with their distinctive call, are a common migrant through and summer resident of Walker Valley.

You may not see any black-throated green warblers but you will most likely hear one of their distinctive calls; the male serenade to females of *zee-zee-zee-zoo-zee* or the warning call to other males, *zoo-zee-zoo-zoo-zee*.

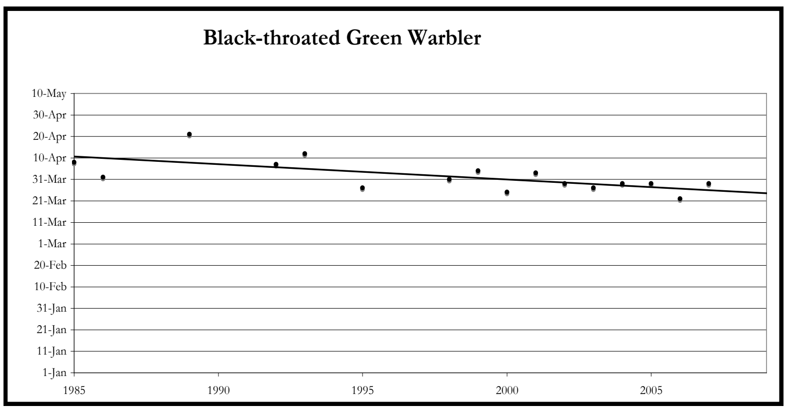


Figure 1. Dates represent the first date the bird was heard in Walker Valley. The date heard is now 16 days earlier than in the mid 1980s.

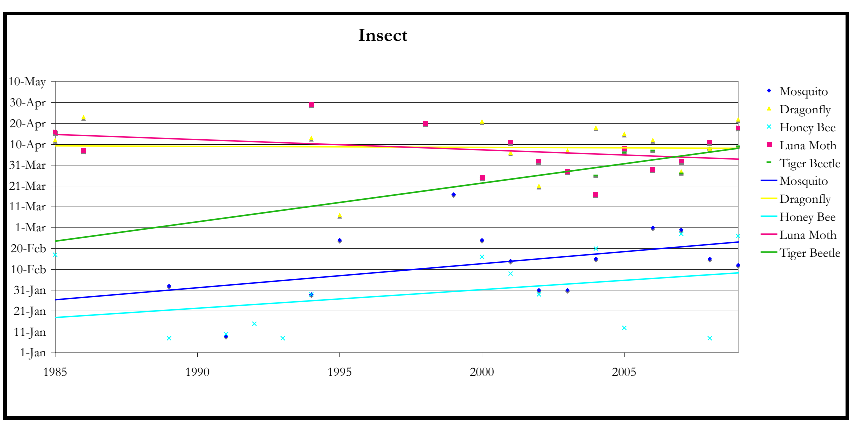
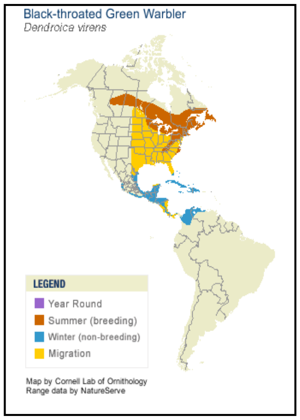


Figure 2. Black-throated Green Warbler's primary food source is insects. The above graph shows the first date several species of insects were spotted in Walker Valley.

DISTRIBUTION

Summer: This bird can be found in the northeastern United States and southeastern Canada. Populations extend north and west into British Columbia and south and west along the Appalachian Mountains.



Winter: They migrate to Central America and northern South America.

Great Smoky Mountains National Park: This bird can be found at all elevations throughout the park in the summer. They are especially associated with eastern hemlock forests.

NATURAL HISTORY

Nesting: The female builds a deep cup nest made out of bark, twigs, grass and lichens, usually lined with fur, rootlets, moss and feathers. Nests can be found on a horizontal branch of a conifer, usually eastern hemlocks.

Diet: They pick spiders and insects, particularly caterpillars, from leaves and twigs of trees.

CONSERVATION BIOLOGY

Populations, overall, have been stable but are showing some decline in parts of its range. Habitat loss on both breeding and wintering grounds has had an impact. Its relationship with eastern hemlocks in the Park could cause a local population decline. This is a forest-interior species. Forest fragmentation will have an impact on populations.

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Black-throated Green Warbler

Questions for the students

- What does Figure 2 mean for the Black-throated Green Warbler?
- Is availability of food going to have an impact on this bird?
- Is there going to be a change in the food source in the early spring?
- Is this enough information to make conclusions?
- Are there other sorts of data that might be more applicable for this species?
- Are these pertinent insect species to be examining? Why or why not?
- How can the data collection techniques used for phenology at Tremont be improved?
- Other than food source, what impacts might humans have on black-throated greens?

Black-Throated Green Warbler Teacher Notes

Black-throated Green Warblers have a wide variety of potential food sources. They will eat many kinds of insects. Climate change will impact different species of insects in different ways. While the sorts of insects that these warblers eat throughout the spring and summer may change, it is unlikely that they will suffer a food shortage. The black-throated greens seem to be arriving earlier, but, at least in the Smokies, there will most likely be plenty of insects that have already emerged.

Forest fragmentation is a larger concern for these birds.

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The local results for climate change are complex and not fully understood. Help students think critically about the needs of this species and what a wide range of potential changes in their environment might mean. Consider warming temperatures throughout their range and changes in precipitation, both in amount and in timing.

Sharp-lobed Hepatica

Hepatica nobilis var. *acuta*

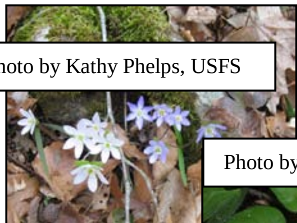


Photo by Kathy Phelps, USFS

Photo by Tom Murray, USFS

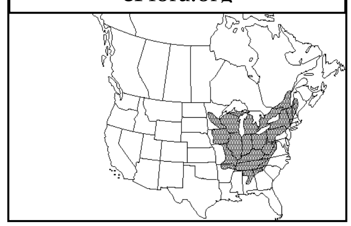
Hepatica is a spring ephemeral wildflower. In the Smokies, it blooms in March or April, taking advantage of the relatively high levels of light reaching the forest floor. The flowers are present for several weeks, dropping its petals before the first leaf out of the deciduous trees above.

Hepatica, or Liverleaf, is named for its leaves, which like the human liver has three lobes. In the Doctrine of Signatures, hepatica was used as a medicine for liver problems.

DISTRIBUTION

Sharp-lobed hepatica can be found across the eastern United States and Canada in rich woodlands.

Sharp-lobed hepatica range map produced by eFlora.org



DESCRIPTION

Hepatica is a small, evergreen plant. The white, blue, lavender, or pink flowers bloom in March or April in the Smokies. After the flowers drop their petals, the plant puts up new three-lobed leaves. These leaves persist, becoming darker green, gray and even a deep brown throughout the fall and winter.

NATURAL HISTORY

Hepatica lives in rich woodland forests with well-drained, loamy soils. The flowering mechanism is little understood in spring ephemerals but the air temperature probably plays an important role. Day length may also play a role as flowers partially close at night and will not fully open on overcast days.

Moisture Requirements: While this plant can tolerate moderately dry conditions, too much sun will damage leaves.

CONSERVATION

Sharp-lobed hepatica is common throughout most of its range. In Maine, this plant has possibly been extirpated. In Connecticut this species is threatened.

SOURCES

PLANTS Database. Published on the Internet http://plants.usda.gov [accessed 30 March 2010] United States Department of Agriculture

Pivorunas, David. Published on the Internet http://www.fs.fed.us/wildflowers/plant-of-the-week/hepatica_nobilis.shtml [accessed 30 March 2010] Celebrating Wildflowers: Plant of the Week. United States Forest Service

eFloras (2008). Published on the Internet http://www.efloras.org [accessed 14 April 2010] Missouri Botanical Garden, St. Louis, MO & Harvard University Herbaria, Cambridge, MA.

Examine the following graphs.

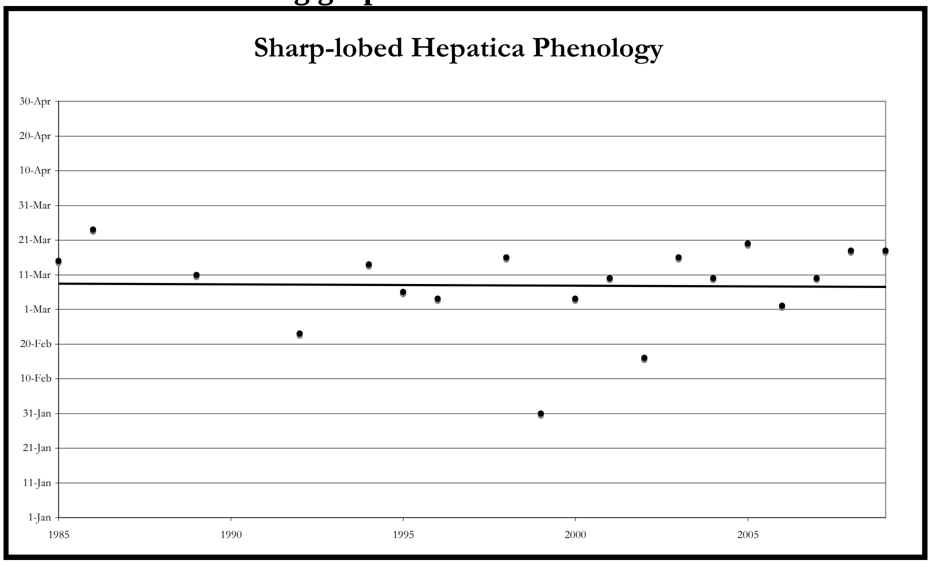


Figure 1. Dates represent the first date that the flower of the Sharp-lobed hepatica was spotted in Walker Valley.

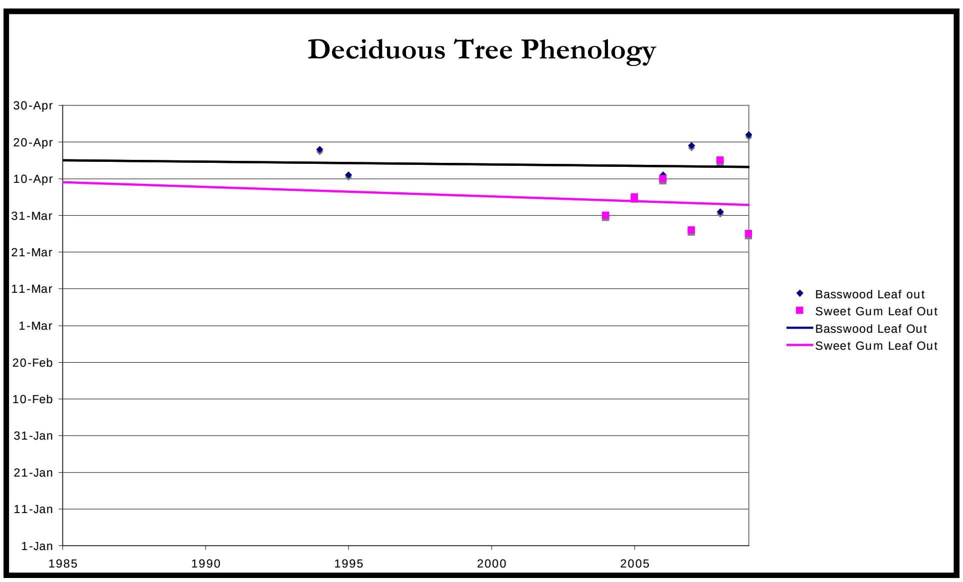


Figure 2. Dates represent bud burst for basswood and sweet gum trees in Walker Valley.

Sharp-lobed Hepatica

Questions for the students

- What does the trend line for the Sharp-lobed hepatica seem to indicate?
- What might cause the hepatica to bloom earlier or later?
- What might happen if the hepatica blooms earlier or later?
- Why are the tree budburst data included?

The deciduous tree graph depicts only two tree species, both with a very limited number of data points. The sweet gum trend line shows a slight trend toward an earlier leaf-out date. In North America, most deciduous trees are dependent on temperature for leaf-out. The buds will not begin to open if the temperature does not get warm enough for long enough.

- What does this mean for the Hepatica in the Smokies if climate change causes a warming in this area?

Hepatica Teacher Notes

Spring ephemeral wildflowers, like sharp-lobed hepatica, bloom in the early spring, before trees have started to develop leaves. They do most of their annual photosynthesis and reproduction in this small window of time. It is not fully understood what the mechanism is that influences these flowers to bloom. It could be related to day length, because hepatica has leaves all winter long. Most likely the air and soil temperature play important roles in triggering the flower. Help the students consider what an earlier bloom time might mean.

- Will this influence the types and number of pollinators available?
- Will pollinators also emerge earlier due to climate change?
- If bloom time does not change, what will happen if deciduous trees develop leaves earlier?
- Is the information included on the graphs enough to make conclusions?
- Are there other sorts of data that might be more applicable for this species?

As the phenology project has taken hold of the imagination of the staff, more people are involved. This might influence the likelihood of certain species being spotted and recorded. This is an important note for the students to consider. Understanding the data means understanding the collection methods, including the shortcomings of such methods.

The local results for climate change are complex and not fully understood. Help students think critically about the needs of this species and what a wide range of changes in their environment might mean.

Activity #3: Practice Maps

Key Concepts

- Students will make group decisions about their phenology maps.
- Students will keep the scale of the drawing as accurate as possible.

Grade Level: 6^{th} – 8^{th} with High School variation

Time: 20 minutes

Materials: Paper, crayons or markers, large whiteboard or chalkboard.

Introduction

Each student will draw a map of his or her school in preparation for making the large map for the phenology project. The group needs to decide what will be included on the map itself. This is something that will be at the school for years, so it has to be clear and accurate. It is important that the group comes to a consensus on the things included and the things left off of the map.

Procedure

1) On your paper, draw a map of your school from a bird's eye view.

2) Make sure to include a key and to label things clearly. Where are the sidewalks, parking lots, trees, gardens, recess equipment? How large are things in relation to each other?

3) When all the students have completed their maps ask a few students to share their maps with the group.

4) Ask the students to compile a list of things that they would like to include on the group map. The teachers from the school will be essential in maintaining accuracy and reminding the students if anything important is left out.

5) There are some questions that will have to be answered before moving on:
   - Where will the final map(s) hang?
   - How big can this map be?

Wrap-Up

Based on the individual maps created by the students, there should now be a comprehensive list of the important features around their school. The group should have arrived at a list that the students and teachers feel confident best represents their school.

Discussion Questions

- How did you try and remember what is around your school? Did you take a mental walk around the building?
- Everyone goes to the same school, but there were differences between what was included on all of the maps. Why?

Pre-Trip Activity Option

This activity would work well at the school. The students would then arrive with a list of important characteristics to include on their final version of the map.

Variation – High School

For older students, the pre-trip activity would include much more detailed information, particularly about scale. By including distances and taking measurements, the group could decide on a scale for their final phenology map (Activity 4).

Activity #4: Mapping Changes

Key Concepts

- Students will create the final phenology map project.

Grade Level: 6th – 8th

Time: 45 minutes

Materials: Large paper, construction paper, markers, rulers, meter sticks, pencils, string, art materials as decided upon by the group.

Introduction

Now the group will create the final product: a phenology list, phenology icons, and a large map to hang in the classroom or hallway at school. The work will need to be divided up to get it all done. The following is written for a group of 10 – 20 students. With a larger group, consider splitting into teams that will complete their own list, icons, and map. The school will then get several maps to hang in different classrooms, or the best map can be chosen and taken back.

Procedure

1) Mapping Team: The mapping team will get the practice maps and the list created in Activity 3: Practice Maps. On a large piece of paper, create a map of the school. Try and make things to scale and put them in the proper places. Use rulers and yardsticks for straight lines. Circles can be created with a pencil and a string. Include a key and a title for the map.

2) Phenology List Team: Based on Activity 1: What is Phenology, the Phenology List Team will create seasonal lists of the changes they want to look for at the school. As a season is finished, pass the list to the Phenology Icon Team so they can begin work.

3) Phenology Icon Team: The Phenology Icon Team will design and create the icons that will be stuck to the school map. They will need to gather information from the other two groups to complete their work. They will need to decide how large things should be based on the size of the map and how much they would like to be able to write on the icons. They must decide if one symbol or color will be used for each season or if there will be different symbols for each occurrence, such as a red leaf for the first red leaf of fall, a flower for the first spring flower, a bird for the first migratory bird of spring, etc.

Wrap-Up

Now that the map, list, and symbols have been created, what happens next? The time you spend at Tremont will help you to become better naturalists. Your observation powers are at their peak. Nature doesn't stop when you leave this national park. Looking at this map, we can see where there are habitats and potential changes to notice. It's your job to look closely, investigate, and keep track.

Post-trip

Next year's students can also make their own map to hang at the school, or this first map can be used for years. The students who created the map become the teachers, instructing the new phenologists about the project and how to add to and maintain it.

This map could become a fundraiser for the field trip to your education center as well! Each year (after the first 12 months are complete) the students could create a phenology calendar for the school. Put the average date for each sighting on a calendar with kid-photography or art as that month's picture.

Check This Out!

- Sign up to enter your data into a national network at Journey North. http://www.learner.org/jnorth/.

- Keep the Phenology Alive! In the fall, join students across the country and plant a Journey North tulip garden. Track the emergence and blooming times of tulips as they spread across the country. http://www.learner.org/jnorth/tm/tulips/AboutSpring.html.

Sources

Project Learning Tree Curriculum Guide. Activity 45: Web of Life. 2004. The American Forest Council, Washington, D.C. 20036 (http://www.plt.org)

How Science Works

Scientific inquiry and the scientific process are topics taught at many outdoor education centers across the country. It is essential that students understand how the scientific process works in order to understand current complex scientific topics like climate change. In addition, in order to understand climate change students must also learn how, as a society, we begin to accept scientific studies as best theories and build consensus around a topic. In other words, students will learn about what happens in the scientific community after the "conclusion" section of the experiment is done and when and why we decide to accept a new theory as "correct." To do this, students must understand what constitutes credibility within the scientific community and how, through things like accurate record keeping, openness, and replication, we build consensus around scientific findings within society.

By understanding historical examples of how popular consensus has shifted over time over a scientific issue, students will see that our gradual shifting of thought surrounding climate change is not a unique occurrence. There are many examples of this shifting of thought in history. For example, we used to think the world was flat, the earth's continents did not move or change, and the sun revolved around the earth. We even had no concept of something as undisputed as gravity. This chapter illustrates one such historical example demonstrating a shift in consensus around a scientific topic and then builds on this with interactive activities focused on climate change.

The Formation of Yosemite Valley

Educator Summary

Using an historical example can help students understand how consensus surrounding scientific processes has shifted dramatically in the past as new evidence has come to light. This can put the current debate in the media surrounding climate change into perspective. The "media," as well as common thoughts and perceptions of the time, has always played a role in the process of societal decision-making and acceptance, a process that often happens slower than the science itself. Ultimately, a theory that stands the test of time, the scrutiny of other scientists, and repeated experimentation should and will prevail.

This activity introduces students to an historical geologic debate and then uses an inquiry approach to have students try to figure out who was right. After examining the evidence around them themselves, students learn about the accepted theory of today.

Key Concepts

- Scientific thought and theories shift over time as new theories are put forth and new evidence is gathered.

- People gradually change their beliefs based on these scientific theories and evidence, but are also influenced by the common perceptions of the time, general resistance to change, political and economic interests, and the media.

Grade Level: 6-12

Materials: Whiteboard and markers, journal/paper and pencil for each student.

Time: 1 hour plus travel time between the two locations of the activity

Introduction

Tell students the story of Josiah Whitney and John Muir's opposing theories over the formation of Yosemite Valley (see "Background" section below). Stop where you see "STOP HERE!" in the text, leaving off the end of the story, which explains what we accept today as the best theory. Then, depending on student's prior knowledge, outline the various different valley formations, including "V-shaped" river valleys, "U-shaped" glacial valleys, and block fault valleys. For younger students, or students for whom these are new concepts, you will need to do other activities about glacial formation and plate tectonics to more thoroughly introduce these topics prior to this activity.

Josiah Whitney vs. John Muir: A Historical Battle of Ideas

(To be presented to students)

In 1860, Josiah Dwight Whitney was appointed Director of the California Geological Survey (Fahy, 1985). He was well qualified for this position, having studied at Yale University and at various schools in Europe. He also had extensive work experience and had been a part of many other field surveys similar to this one.

Whitney and his crew spent four years surveying most of California including Yosemite Valley. This means that they mapped the areas, including the types of rocks and the geologic formations, and tried to explain how everything had come to look the way it did. The origin of Yosemite Valley posed a difficult geologic question with its steep granite valley walls, flat meadow-laden bottom, and absence of talus slopes (piles of rocks at the base of the cliffs) (Smith, 1987). It had a more rectangular cross section rather than a typical V-shaped river valley or a typical U-shaped glacial valley.

Some scientists that had examined the valley before Whitney's team got there found what they thought was evidence of glacial activity both in the high country of Yosemite all the way down to the face of El Capitan (Optional question: What types of things might they have observed? Ex: Glacial polish and chatter marks, other U-shaped or hanging valleys, cirques, glacial erratics, and moraines). However, in response to these claims, Whitney asserted that "there is no reason to suppose… that glaciers have ever occupied the Valley or any portion of it" (Smith, 1987). Whitney believed that because the features he saw in Yosemite Valley were so unique (Optional question: Have you ever been anywhere that looks like Yosemite Valley?) it must have been formed in a unique way. "Even the most casual observer must recognize in it a new revelation of mountain grandeur… It is entirely unique in the Sierra Nevada: and as so far as we know, in the world" (Whitney, 1868; 1869). Whitney came to the conclusion that Yosemite Valley was created by a cataclysmic sinking of the valley floor during a massive earthquake. This concept, known as block faulting, is not unknown in this area and is thought to have formed the Lake Tahoe Basin and the Owens Valley.

Around the same time, John Muir was making his own observations in Yosemite. Muir was a Scottish-born naturalist whose family immigrated to Wisconsin. In general, he lacked formal scientific training or background. He did take college classes in geology and botany at the University of Wisconsin-Madison (enough to get him very interested in the topics!), but he never graduated. After much travel he ended up in California in 1868; he worked in Yosemite as a shepherd, designed a water-powered mill, and built a house along Yosemite Creek. In his free time he would explore Yosemite, making detailed sketches of the landscape and journaling vigorously about what he saw and experienced. From his personal observations he came up with his own theory about how Yosemite Valley and the surrounding area had been formed. He argued that Yosemite Valley had been carved by glaciers. He believed that glaciers had covered all of the Yosemite area and beyond, extending through the Central Valley to the Pacific Ocean. As evidence, he cited abundant glacial scorings in Yosemite Valley and glacial polish and living glaciers in the high country. In 1871, Muir discovered an active alpine glacier below Merced Peak, which helped his theories gain credibility. Whitney strongly disagreed, stating that "Much less can it be supposed that the peculiar form of the Yosemite is due to the erosive action of ice: nothing more unlike the real work of ice, as exhibited in the Alps, could be found" (Whitney, 1869). Muir was considered by most in the scientific community as an amateur and a "mere sheepherder," and his glacial theory was not widely accepted.

This controversy and debate between Muir and Whitney continued for many years with the preeminent geologists of the time unable to agree on a common theory.

(STOP HERE!!!)

An earthquake hit the region in 1872, causing several rockfalls along the valley walls but no further cataclysmic collapse. This made some people start to consider Muir's theory more seriously. However, geologists still could not agree, and the controversy continued.

Widespread agreement was finally found on this topic after Francois Matthes lead a comprehensive study of the valley funded by the U.S. Geological Survey (Fahy, 1985). His findings, published in 1930, (70 years after Whitney's original survey of the valley) were very thorough and became the new authority on the topic. Matthes' explanation was that the Merced River first eroded a V-shaped canyon which was later changed by glaciers which occupied it. He believed that the last advance of the glaciers was about 3,000 years ago and extended to just beyond El Capitan. His theory went on to say that the melting of the glacier behind the terminal moraine produced a lake which was later filled by sediment, creating the flat and meadow laden-valley floor we see today (Fahy, 1985). This theory, with some changes and modifications, has held up to the test of time, and is close to what today's scientists believe happened.

In the end, although Matthes largely discredited Whitney's theory, he did acknowledge the visual evidence that made it seem probable, stating, "Looking down the Yosemite Valley… one readily gains the impression that the chasm is an abnormal abyss that lies sunk deep below the general level of the land" which "strongly suggests that the Yosemite [Valley] was produced by a rupturing of the earth's crust or by the caving in of a portion of it" (Matthes, 1930). Additionally, although Matthes' work supported Muir's central idea that glaciers played an important role in the formation of Yosemite Valley, he did disagree with many of Muir's ideas. He believed that Muir largely exaggerated the extent and role of the glaciers. Current scientific thought today still agrees with most of what Matthes proposed, and thus supports Muir's ideas (with some significant modifications) more than Whitney's.

In this story of the debate over how Yosemite Valley was formed we see that it took nearly a century of scientific thought, inquiry, and gathering of evidence to come up with a theory that was consistently accepted by scientists and lay people. In science, the theories that hold up to the rigorous testing and scrutiny of other scientists, and still seem plausible and likely in light of new evidence discovered, will emerge as the dominant theories and eventually be accepted by most people as such.

Procedure

1) Have students divide their paper into two halves. Mark one side Whitney/Block Fault and one side Muir/Glaciers. For each side have students draw what they would think the valley would look like if Whitney's theory of cataclysmic collapse was correct and what it would look like if Muir's theory of glacial formation was correct. Then have students list at least three defining features or things they would look for to support each theory.

2) Come together as a group and have students share their answers and drawings. Develop a group list on your white board of what we would look for to support either theory.

3) Hike as a group to a valley overlook point, a glacial moraine or other spot where students can view direct or interesting evidence of valley formation. Discuss what evidence students can see and which theory this evidence supports. Ultimately, lead a discussion about which theory they think is correct including the following questions: Does this landscape look more like your drawing of Whitney's or Muir's theory? Are there things that don't fit either theory? Based on the evidence you can see, how do you think the valley formed? See "discussion questions" below.

4) ART EXTENSION: A good way to do the last step of this activity, if you have more time, is by talking about observational sketches. This is a technique that John Muir used often to compile evidence for his glacier theory. Consider starting by having students sketch a small object of their choice using blind-contour techniques*. Stress that students should focus on capturing the details of their object rather than worrying about

the scale or accuracy. When they are done with that drawing, have students draw a landscape of a section of Yosemite Valley that encompasses some rock formation. This one is not a blind-contour drawing (They can look down now!), but they should still keep the same focus on capturing the details and unique features of the particular formations in their drawing. It is more important to capture every little crack, crevice, pattern, and shape of their formations than to draw realistically or in proper proportions.

5) Come together as a group and share and discuss your drawings. Possible discussion questions are listed below.

   * In blind contour drawing students must draw something using one continuous line without ever looking down at their paper. They should be continually staring at the object. The idea of this technique is to focus on the details of the object, rather than the proportions or accuracy. At the end you can do an extra fun drawing where they do blind contour drawings of each other's faces.

Wrap-up

Read students the "end" of the story of Muir and Whitney above. Does this agree with what students thought based on the evidence they observed? With older students, end with a discussion about forces that act in opposition to accepting new scientific theories.

Discussion Questions:

- Why is Yosemite Valley a "tricky" geologic question? What is confusing about it?
- Is there any evidence that you observed that is conflicting or doesn't fit either theory?
- What other evidence would you need to make a decision about which theory you would support?
- Do you have your own theory? What do you think really happened here?
- Why do you think people discounted John Muir's theory despite his abundant evidence?
- What are things that most people need in order to believe a new scientific theory?
- Can you think of an example of a scientific debate that is going on today? (Try to eventually make the connection to Climate Change).
- Where are we as individuals and as a society in this debate over climate change? Is it a scientifically accepted theory? Is it a socially accepted theory? What forces are acting in opposition to society accepting this theory?

ART EXTENSION QUESTIONS:

- Does your landscape drawing look more like your drawing of Whitney's or Muir's theory?
- How do you think John Muir and Josiah Whitney collected "evidence" of their theories? (They did exactly what the students just did: Careful drawing and observation of many locations in Yosemite!)

In the Classroom

This type of activity can easily be done in a classroom as a pre- or post- trip activity using an alternative scientific historical debate example, such as the one mentioned in the section below. An excellent post-trip classroom activity would be to make a timeline of the history of the climate change scientific debate, with each student featuring one scientist and his/her contributions. See the **"Diving-In"** section below for more details on how to do this.

Variations

The historical debate over the formation of Yosemite Valley is just one example that can be used in order help students understand how consensus about scientific issues shifts over time. Other historical examples can be used that are more appropriate to your location. It is best if the historical example used is an issue that students can observe directly in order to weigh the evidence themselves.

For example, the historical debate over plate tectonics is an excellent example of a historical scientific debate that is relevant everywhere. This example is great for a classroom because students can make direct observations by looking at a map of the world. For more information on this historical debate check out:
http://www.enchantedlearning.com/subjects/dinosaurs/glossary/Contdrift.shtml,
http://en.wikipedia.org/wiki/Continental_drift

There are many other examples of scientific topics debated in history such as evolution, the revolution of the earth around the sun, and the shape of the earth. Other national parks also have relevant examples of historical scientific debates. For example, the formation of the Grand Canyon, the causes of the geysers in Yellowstone, and the winter migration of birds were all at one time unsolved mysteries.

Extension: How does Climate Change fit in?

The debate over the effect of atmospheric carbon dioxide and human-caused climate change has a long history that largely mirrors these examples. This debate is only "recent" in popular media and politics. Much like the other examples above, scientists have been collecting data and debating these issues for over a century. Scientists first started considering the affect of carbon dioxide in our atmosphere and its relationship to temperature in the 1800's. The famous

Keeling Curve, which measures atmospheric CO_2 in Hawaii, uses data collected beginning in 1958. The New York Times published an excellent time line of this debate, featuring the contributing scientists from around the world (See "Check This Out" section below, "Climate Change Overview" #4). It may be helpful for students to see this timeline to understand that the debate over climate change is not new or radical in the scientific community. The evidence has been mounting for almost two centuries, and it is just now that it is finally being examined and accepted by politics and society. It may take even longer before our understanding and acceptance of this scientific knowledge effectively impacts our individual and societal behaviors.

Science Throw-Down "Kubb"

Educator Summary

Kubb is pronounced "Koob" and is an originally Swedish lawn game. This interactive activity uses this traditional and fun game to show students how new theories become accepted over time. Things such as replication of experiments, openness and transparency, accurate record keeping, excellent methodology, and sound reasoning add credibility to a given theory. These are the underlying principles that define "good" science and eventually help us understand how things work in our world.

Key Concepts

- New scientific theories may come to be accepted as best and others may get discounted.
- Replication of experiments, openness and transparency, accurate record keeping, excellent methodology, and sound reasoning add credibility to a given theory.
- A theory that stands up to the scrutiny and testing of other scientists will eventually become accepted by science and society.

Grade Level: 8-12

Materials:

- 10 "Kubbs" or blocks of wood or anything that can be stood up and knocked over by the sticks. See picture below to get an idea of typical sizes and shapes.
- ~ 6 throwing sticks (or fewer if you reuse them during the round or have fewer students)
- 1 "King" or slightly taller/special block of wood or object that you can knock over
- Something to make boundaries (backpacks work well!)

- ~ 12 students (fewer is OK, many more would be hard)

Time: 45 mins

Introduction

First check if students have a good understanding about the scientific process. Do they understand what it means to conduct a scientific experiment? Either individually or in groups, have students brainstorm a list of what makes a scientific experiment good or credible and what makes one bad or faulty. Come together and make a master list. Possible ideas to include on this list are proper control of variables, replication, accurate record keeping, openness and transparency, sound methods and reasoning, honesty and integrity, and others.

Then ask the students, "How do we get from a single scientific experiment to a scientific theory?" This process often occurs when many experiments are done over time on a given topic and point to a similar conclusion. Go back to the list of things that make scientific experiments credible, and ask students if there's anything additional needed to make scientific theories credible. Ask the students if any additional things need to be added to the list. Mostly the list is the same, but things like replication take on a new meaning. The new theory must hold up to further testing in light of new evidence while maintaining all of the virtues listed above that make for sound science.

Explain that the game we are about to play is about how we decide if a new scientific theory is valid. The list we just made defines the characteristics that make a scientific theory credible. These are necessary pieces without which the results are meaningless. But we need more than just credible science to decide if a scientific theory is valid. The theory also needs to be supported by further evidence and experimentation, and there must not be much evidence found that is opposing or unexplainable in the context of the theory. This process takes time and is always happening in science as we gradually shift our thoughts about a topic and make new discoveries. Some examples that students might know about already are our shift from thinking that…

1) the sun rotates around the earth to the earth rotates around the sun

2) the earth is flat to the earth is round

3) continents are fixed to the crust of the earth constantly shifting

Scientists facilitate this shift gradually, by "throwing rocks" at each other's theories, or testing them with various experiments and observations, and seeing if they "still stand." They will also critique them, looking for things missing from the credibility list. In this game we are going to do exactly that. We will literally throw sticks at each others' blocks, which represent two opposing theories on the same topic.

For older students, try to brainstorm a few current topics with opposing theories. This list could include evolution vs. creation, human caused climate change, the age of the universe, nature vs. nurture, and many more.

Procedure

1) This game is played exactly like Kubb. See the diagram below for the set up. Use backpacks for the "corner stakes."

2) Divide your group into two teams. Each team represents a group of scientists who have found evidence that supports a common theory. The two teams support opposing theories (for example, one team found evidence that the world is round and other found evidence that the world is flat). It is probably best to use an already settled debate so that the game doesn't suppose to draw new conclusions (or conclusions you don't want it to draw!).

3) Each of the 5 Kubbs on both sides represents one of the pillars of scientific credibility: proper control of variables, openness, replication, accurate recordkeeping, and logical methods and reasoning. It is best if you write these on the Kubbs themselves.

4) The King represents unequivocal and abundant evidence against your opponents' theory (for example, the fact that people sailed around the globe and didn't fall off).

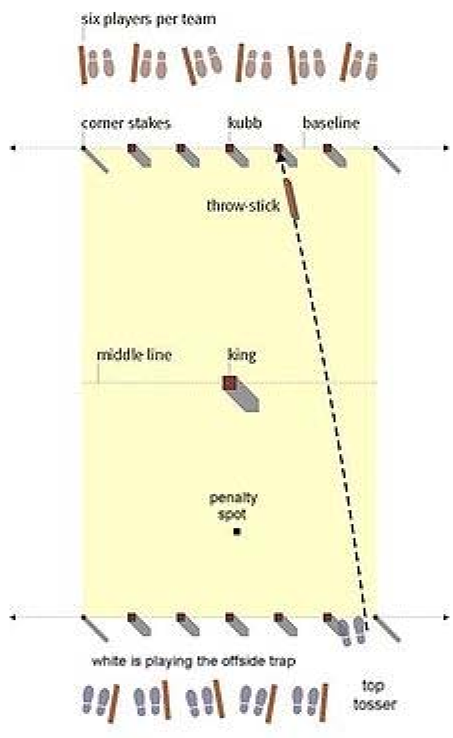
5) The goal of the game is to "knock down" your opponents' theory by finding faults in the essential qualities of sound science. As you do this, you gain more evidence (Kubbs become evidence when they are added to your side as field Kubbs). Lastly when your team successfully knocks down the King you have won by DISPROVING your opponents' theory with abundant evidence that does not support it. It does not necessarily PROVE your theory is true. This cannot be done in this game.

This is how you actually play Kubb:

1) Team A throws the six (or however many) sticks, from their baseline, at their opponent's lined-up Kubbs (called Baseline Kubbs). To increase learning, have students say the name of the tenant they are aiming for (It's OK if they knock down a different one.). Throws must be under-handed, and the sticks must spin end over end. Throwing sticks sideways or spinning them side-to-side is not allowed. Make sure that students **stand away** from the area being thrown into!
2) Kubbs that are successfully knocked down are then thrown by Team B onto Team A's half of the pitch, and afterwards stood upright. These newly thrown Kubbs are called *field Kubbs*. Deciding where in the opponent's half to throw the field Kubbs is a very important part of the strategy. Encourage the students to strategize as a team about where to throw it. Have a different student throw it each time.
3) Now Team B throws the sticks at Team A's Kubbs, but must first knock down any standing *field Kubbs* before knocking over any baseline Kubbs (if a baseling Kubb is

accidentally knocked down, just stand it back up again). Field Kubbs that are knocked down are taken out of play for the rest of the game. Again, baseline Kubbs that are knocked down are thrown back over onto the opposite half of the field and then put upright.

4) If either team leaves field Kubbs standing at the end of their turn, the Kubb closest to the king now represents that side's baseline, and throwers from that side may step up to that line to throw at their opponent's Kubbs.
5) Play continues in this fashion until a team is able to knock down all Kubbs on one side, from both the field and the baseline. If that team still has sticks left to throw, they now attempt to knock over the king. If a thrower successfully topples the king, they have won the game.
6) In traditional Kubb, if at any time during the game the king is knocked down by accident, the offending team immediately loses the game. However, for this version, have the offending team act as if one of its baseline Kubbs was knocked down.



A typical Kubb set (picture care of Wikipedia)

Wrap-Up

Discuss what happened in the game. What "pillars" of sound science got knocked down for each team? What would this mean if this was a real world debated issue? Follow with further discussion questions.

Discussion Questions

- What was realistic about this game? What was unrealistic?
- What other variables would factor in to a real scientific debate? (politics, economics, media, social norms)
- Let's talk about a currently debated (at least in the media) issue: Climate Change. If climate change were the issue in this game, where do you think we are right now? Which pillars are standing? Which have been knocked down?
- How are other variables (media, politics, etc.) changing the debate about climate change? Are the media, politicians, and other players properly examining the tenants of strong science we looked at in this game?
- In real life, can pillars be stood back up after they have been knocked down? (Yes! If a theory is knocked down for not having enough replication, over time additional evidence can add the necessary replication. Something that was previously criticized for not being open or transparent could become so.)

In the Classroom

This game can be played anywhere, including a schoolyard. It is best related back to science being done in the classroom, especially experiments. Students are more accustomed to identifying the steps of the scientific method in their labs (hypothesis, methods, etc.) but are much less used to evaluating their overall experiment in the context of these tenants of credible science. Doing this would be an excellent lesson in how science works as well as building critical thinking and evaluation skills. Would they really trust their own work?

Diving In

Climate Change Information: Who are the players and who can you trust?

It is important for educators to understand where information about climate change comes from. Thousands of studies that relate to this topic are being conducted all the time by scientists around the world. There is far more information being published on climate change than any one person could sort through. So where should you go for good information and who should you trust?

One very highly regarded institution is The Intergovernmental Panel on Climate Change (IPCC). They have taken on the challenge of sifting through all the scientific literature that is available and drawing overarching conclusions with associated levels of certainty. The IPCC is open to all member nations of the UN and the World Meteorological Organization (WMO) and is composed of representatives from 194 nations. As identified on their website, the IPCC is "established by the United Nations Environment Programme (UNEP) and the WMO to provide the world with a clear scientific view on the current state of climate change and its potential environmental and socio-economic consequences." The IPCC reviews and assesses current research, but does not conduct any original research itself. Its findings are delivered in a large document called an "assessment report." The forth and most recent report was published in 2007. The first was published in 1990. The IPCC strives to include only peer-reviewed literature. There has been recent controversy over two errors in the 2007 report, one of which had its source in "grey" literature, rather than from peer-reviewed published work (Max, MSNBC). The IPCC acknowledged these errors, but pointed out that they do not undermine the overall conclusions of the over-3,000 page document. The organization was given the Nobel Peace Prize at the end of 2007 (IPCC). Because of the organization's intergovernmental nature, which requires that all member nations ratify the document, it is often thought of as a reasonably conservative document and thus may be a good informational basis for education.

There are also several U.S. government organizations with excellent websites containing climate change information. Websites are listed in the "Check This Out" section below.

What does it mean if something is "peer-reviewed," and what is "grey" literature? Peer review "is the process of subjecting an author's scholarly work, research, or ideas to the scrutiny of others who are experts in the same field" ("Peer review"). Practically, peer review is the work done during the screening of manuscripts submitted to journals and funding applications. This process encourages authors to meet the standards of their discipline and "prevents the dissemination of irrelevant findings, unwarranted claims, unacceptable interpretations, and personal views" ("Peer review"). Publications that are not peer reviewed are often regarded with suspicion by other scientists and professionals. The term "grey literature" is used to define work that has not gone through the peer-review process. The peer review process is essential to science because it is the way that new information and studies are checked for the "pillars of sound science" focused on in the second activity.

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Check This Out!

Included in this section are a list of websites and resources to help educators gain further knowledge on climate change issues.

Climate Change Overview

1) Union of Concerned Scientists have written up a summary of the IPCC Fourth Assessment Report (4 pages with graphs and pictures): http://www.ucsusa.org/global_warming/science_and_impacts/science/findings-of-the-ipcc-fourth-2.html

2) Want to go more in depth into the IPPC? The "Summary for Policymakers" (more abbreviated) and the IPCC Synthesis Report (less abbreviated, 45 pages) can be found at: http://www.ipcc.ch/publications_and_data/ar4/syr/en/contents.html

3) Still want to learn more? *The Rough Guide to Climate Change*, by Robert Henson (second edition, published January, 2008) is a readable guide to the topic of climate change and was shortlisted for the Royal Society prize for science books in 2007.

4) This is an EXCELLENT summary of the history of climate change scientific understanding. Mentioned above in "Variations" section of the first activity. http://www.nytimes.com/interactive/2009/12/07/science/20091207_CLIMATE_TIMELINE.html?ref=earth

Good Informational Websites

1) www.ipcc.ch (Intergovernmental Panel on Climate Change)

2) www.globalchange.gov (United States Global Change Research Program)

3) http://www.nps.gov/climatechange/index.cfm (National Park Service website with information specific to National Park issues)

4) www.noaa.gov/climate.html (National Oceanic and Atmospheric Administration)

5) http://www.epa.gov/climatechange/basicinfo.html (Environmental Protection Agency)

6) http://www.ucsusa.org/global_warming/ (Union of Concerned Scientists, a non-profit organization)

Managing our Parks and Natural Resources

The National Park mission statement reads as follows:

> "The National Park Service preserves unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations. The Park Service cooperates with partners to extend the benefits of natural and cultural resource conservation and outdoor recreation throughout this country and the world."

This is a noble and multi-faceted mission and thus can sometimes be difficult to fulfill, especially in the face of new challenges. We have seen challenges face our parks in the past and the difficult and often controversial decisions that followed. For example, San Francisco needed a new water supply to support its burgeoning population after the 1906 earthquake and resulting fire. The solution to this problem was the O'Shaughnessy Dam which was built on the Tuolumne River in the valley known as Hetch Hetchy inside Yosemite National Park. This dam drastically changed the ecosystem of a natural area in the park, converting a meadowed valley to a lake bottom. But this dam also provided clean drinking water and hydroelectric power to many residents of San Francisco. Another such historical conflict has been whether or not snowmobiles should be allowed in National Parks to help provide visitors with winter access. Different parks have interpreted the NPS mission statement in different ways regarding this issue, resulting in opposite management strategies. Many such conflicts of interest and management have arisen during the nearly 100 years since creation of the National Park Service.

Today we are faced with another such challenge, one that is threatening all of our national parks simultaneously and posing a wide array of management questions. How will climate change affect our parks, and what management decisions should be made to "preserve unimpaired the natural and cultural resources" within them?

This section is designed to help students begin to understand the complex decision making processes that go into managing any place or group. The three following activities will help students understand what a national park is and the challenges of making wise decisions for the future of our parks, especially within the context of climate change. Students will begin to understand ways that resource managers and the National Park Service will, and already do, take climate change in to account when making decisions. Advanced students will understand that symptoms of a changing climate may interact with other, unrelated, human impacts, disturbances, and management decisions, creating the need for deeper understanding of natural systems and more comprehensive management strategies.

For younger students, the concept of managing for the impacts or potential future impacts of climate change will likely be too complex to grasp. However, these students will learn what a national park is, as well as the concept that the earth has many resources that are important to humans and can be used or protected in different ways. These are the essential building blocks to eventually understanding how one could manage resources in the face of climate change. The activities below can be taught in their simplest form and still be useful tools to help students eventually become literate in science and climate change.

Build-A-Park

Educator Summary

This activity is designed to help students understand some of the different, and often conflicting, considerations that go into managing a national park or protected wilderness area and how parks might try to manage resources in the face of climate change or other stressors.

Using materials from the natural world (or with markers and oversized paper or other building materials if in a classroom) students will build their own miniature parks and make five rules for their parks. They will then view each other's parks, hear the National Park mission statement, and finish by discussing the difficulties of fulfilling the statutes of a national park mission statement especially in the context of challenges like climate change.

The additional questions for the students partway through the activity are given based on the assumption that students already have some working knowledge of how climate change is predicted to affect the natural area they are discussing. This activity is thus best if it follows lessons about the natural environment you are in, climate change, and the interaction of the two.

This activity works well either in a classroom or outside in a natural area. It can be done outside using natural materials while students are visiting a national park or other managed recreation area. It also works well as a post-trip activity to get students thinking about the fact that decisions about park management will be in their hands in the future.

Key Concepts

- Managing public lands is difficult and often involves balancing what is best for many different resources and the desires of many different people.
- Climate change is another challenge that is facing park managers and must be considered as a part of management plans.

Grade Level: 6^{th} – 8^{th}, with High School Variation

Materials: A card with the NPS mission statement written on it, 1-3 copies of cards with each of the words “enjoyment,” “education,” “inspiration,” and “preserve unimpaired,” whiteboard and dry erase markers, journals/paper and pens for notes (at least 1 per group), markers and large paper or other building materials if doing this as an indoor activity, optional: a map of the park you are visiting.

Time: 1.5 hrs

Introduction for Students

Ask the students why this park is here. "Why do government protected lands exist?" Have students brainstorm a list of reasons. Lead into the main activity by saying that parks have to take all of these into consideration when they come up with rules/laws about how to run the park. The students will now have a chance to consider these things while designing their own parks.

Procedure

1) Tell the students they will now be building their own parks out of natural materials on the ground (or drawing their park on a large sheet of paper if inside). Split the students into four groups, and give each group a word or phrase (These are taken from the NPS mission statement, but don't tell the students this yet!). For younger students, make sure to define the words on the cards. An optional 5th group can be added that has all 4 word cards.

2) Instruct each group that they have 15-20 minutes to build/draw a park. They can make their park however they like and put whatever they want in it. Encourage them to get creative! For example, a group with the word "Enjoyment" might choose to build an amusement park. Or they could build a nature reserve that has different activities available. The only restriction is that their park must uphold the spirit and meaning of the word or group of words that they were given.

3) Tell students to write five rules/laws for their park to ensure that their park's "mission" or word is upheld. If the students need more direction, explain that these words are in relation to "the natural and cultural resources" in their park, whatever those may be (Enjoyment of… Education of… Preserve unimpaired… "the natural and cultural resources"). They get to decide what the natural and cultural resources of their park are.

4) Lastly, tell students to name their park.

5) After about 15 minutes, or whenever the students are nearing the end of the above assignment, give them the following additional issue to work on as a group: "Park scientists tell you, as the head of your park, that climate change is already starting to affect your park and is predicted to affect it even more in the future." Ask them to write down:

   - 3 things that they are concerned about for their park in the face of climate change

   - 2 changes they would make to the way the park is set up

- 1 rule they would add

6) When the groups are finished with the above steps, go on a tour of their parks, visiting the group that got all five words last. Have each group present their park and its rules, and talk about why they built it the way they did in the context of their word(s). Also ask them to explain their answers to the questions about climate change.

Wrap-Up

Once the parks tour is done, ask the all the students what the major differences were between the different groups' parks. What is difficult about designing a park that upholds all five words? How did these difficulties affect decisions about managing for climate change?

Read the students the NPS mission statement:

> "The NPS preserves unimpaired the natural and cultural resources and values of the national park system for the enjoyment, education, and inspiration of this and future generations."

You can finish by asking the students for examples they have seen (or expect to see) of the park managing for each of these 5 things. Is NPS doing a good job of upholding the mission in this park? For a longer, more intensive discussion, see questions below.

Discussion Questions

- Why is it hard to uphold all five values?
- What did your group change when managing for climate change? What problems did you anticipate?
- What was difficult about managing for climate change? Are there problems that you anticipated that you couldn't manage for?
- How does climate change interact with other stressors to the ecosystem (Other factors such as development, visitor use, invasive species, etc. could alter the way climate change affects ecosystems. Often it is the presence of multiple stressors that leads to species die-offs and other ecological problems.)
- What other problems besides climate change might be facing the park?
- What problems might face the park in the future?
- What would a park look like that only had the words Preserve and Unimpaired? (They might have seen one group's version).
- Are there any parks like this? (Here you can discuss the idea of wilderness and the wilderness act). Should all parks be "wilderness?" What kind of park is "better?"

- Is the NPS doing a good job of upholding the mission statement in this park?

In the Classroom

As discussed in the above lesson plan, this activity works well as a pre or post-trip activity in the classroom. Large sheets of butcher paper and colored markers or building blocks, legos, etc. help maintain the creative spirit of the activity.

Variations

To make this activity more challenging for older groups, add the fifth group that gets all four word cards. You can also give groups two words each. This could be done according to the example below:

Group 1: Enjoyment and Education
Group 2: Education and Inspiration
Group3: Inspiration and Preserve Unimpaired
Group 4: Preserve Unimpaired and Enjoyment
Group 5: Enjoyment, Education, Inspiration, Preserve, Unimpaired

It is easy to take this topic to a deeper level by asking more complex questions about the dichotomy between different ideals and the possible interactions between development, other environmental stressors, and climate change. Several examples are listed above.

Alternatively, to make this activity simpler for younger students who may not yet understand climate change or its implications, leave out the additional climate change questions.

Check this out!

You can get a map that shows all of the federally protected and Indian lands in the United States, broken up by managing agency (BLM, Forest Service, Park Service, etc.). This can be shown before or after the park-building activity begins, to help the students think about the concept of protected lands. You can even go deeper by thinking about the slightly different goals or missions of the various management agencies. The map is available through http://www.nationalatlas.gov/wallmaps.html#fedlands for $9 plus shipping.

This activity is modified from a lesson plan written by Kim Brewitt and based on lessons done by many Yosemite Institute instructors.

Kiwoogie National Park

Educator Summary

This activity is based on basic ecological principles like predator-prey relationships and ecosystem change, and essential math skills like relationships between numbers and graphing.

However, this lesson goes deeper than a typical food chain lesson by delving into issues of land use choices, conservation, development, park management, and the effects of climate change on ecosystems.

In this activity students will play a game inside the boundary of the "park" (a large circle of backpacks), in which they will be either a predator or prey. The game will last at least 5 rounds and the population size of the two animals will be graphed and compared. A discussion about the animals, park management, humans' roles, and climate change will close the activity.

Key Concepts

- Organisms affect each other via the food chain. The population size of one organism can have a large effect on the population of another organism, potentially through a predator/prey relationship.
- Changes in available habitat affect plant and animal populations.
- Outside stressors, such as development, visitor use, and climate change affect the plants and animals that live in an area.

Grade Level: 6 - 10

Materials: A Woogie mouth (can be a sponge, stuffed animal, or anything else soft and throwable), white boards (ideally two), two white board markers in different colors.

Time: 1 to 2 hrs (depending on how in depth your graphing and wrap-up is)

Introduction

Explain to students that they have entered an amazing island called Kiwi Island, named after a particular grass called Kiwi Grass that grows there. It is a mountainous island with a low-lying coastline that gradually rises towards the highest peaks in the center of the island (this will be important later on). Tell them that we are all going to play a game about the plants and animals that live on this island and the story of what happened to them.

Procedure

1) Have all students (minimum 20, more is better!) make a large spread-out circle and place their backpacks behind them. This will serve as the national park boundary for the game. All students and adults will be active players in this game. Students will be either a Kiwi or a Woogie. Adults will be automobile drivers, and some will also fill the roles of the various stakeholders, as they appear in the game, including Joe Camper, Mr. and Mrs. Highbrow, Steve Skibum, etc.

2) Tell the students that by standing on the island they have become a Kiwi animal who eats the grass. Kiwis run around (or walk fast: a fast-walk-only rule works best for this game) squealing "kiwi kiwi" and waving their arms high above their heads.
3) Kiwis have a natural predator called a Woogie. Choose two students to start as the original Woogie pair. The Woogies make a deep grunting noise, saying "woogie woogie," and swing their arms low like an ape. Woogies have a communal, detachable mouthpart. They eat a kiwi by throwing the soft ball or "mouth" at it and hitting it. However, a Woogie cannot move once it is in possession of the "mouth," so it must either pass the mouth to other Woogies or try to "eat" (tag) a kiwi. If a kiwi is eaten, it will move up the trophic levels (or the food chain, from a primary to a secondary consumer) and become a Woogie.
4) Count the total number of kids and start round one. After a few minutes stop the round and count the number of kiwis and the number of Woogies. Write these totals on a white board, set up so that multiple rounds can be recorded. At the end of every round you will record these numbers. During the first round call all adults in to fill them in on different roles they will be playing throughout the rounds.
5) After the first round, explain that Kiwi Island has been discovered and turned into a National Park. Further, every national park has a superintendent. (Assign another instructor or a capable chaperone this job ahead of time). The superintendent will introduce him/herself with theatrics. He or she will then get a phone call from a scientist asking for permission to conduct research in the park and build roads in order to access areas for this research. The superintendent agrees and also hires some rangers to monitor the scientists and roads. Visitors use these roads now, too. Now all chaperones are scientists, rangers, or visitor drivers and will remain so for the rest of the game. They walk about on the island, pretending to be driving a car and making car-like noises, trying to "hit" the Kiwis and Woogies by crashing into them, literally. If a Kiwi is hit by a car it becomes a Woogie (it is eaten as road kill) and conversely if a Woogie is hit it becomes a Kiwi (decomposes, turns to soil, fertilizes Kiwi grass, is consumed by a Kiwi). If you finished the round as a Woogie, you start the next round as a Woogie, and likewise with Kiwis. Play a round with the cars, stop the round, and record the totals of each animal.
6) Follow this with several more rounds, highlighting management and development issues that are most relevant in your park. The following example rounds are a mix of development and climate change issues that would affect this island ecosystem. Choose a few of these rounds to play.
7) **Round 3**: The superintendent receives a phone call from "Joe Camper" (another chaperone or instructor) who wants to be able to camp in the park, saying something like, "I love this park so much that I want to stay for more than just a day trip!" The

superintendent agrees and a small section of the “park” is cut off (move a few backpacks in a few feet) to create the campground. Development eliminates the Kiwi grass; no Kiwis or Woogies can live there, and this new campground area is now out of bounds.

8) **Round 4**: Due to global climate change, the average annual temperature rises 1˚ C (about 2˚ F), and the Kiwi grass, a cool/wet weather specialist, can no longer grow in the lowest elevations of the island. Have students move the backpack ring boundary in a few steps to represent this new boundary of Kiwi and Woogie habitat. Although the park itself still its original size, this habitat is no longer suitable for the animals.
9) **Round 5**: The superintendent receives a call from a "Mr. and Mrs. Highbrow," who want a fancy hotel to stay in. The superintendent recognizes that by having a fancy place for people to stay more money can be generated for the park, so he or she agrees, and another section of the park is cut off by backpacks to make room for the hotel. This section is now out of bounds.
10) **Round 6**: The temperature increases 3˚ C, and sea level rises by 2 feet. Although most of the island is unchanged because of its large relief, the estuary and area of surrounding lowlands become flooded and unusable for Kiwis and Woogies. This area is now a wetland and is taken out of the game.
11) **Round 7**: Superintendent receives a call from "Steve Skibum," who would love to come "shred the gnar" and “ski the pow” on Kiwi Island’s mountains. Can the superintendent build a ski resort? Superintendent agrees, and more of the island is cut off for this development.
12) **Round 8**: Historically, Kiwi Island has a Mediterranean climate, with most of its precipitation falling in the winter in the form of snow. Now, because the average temperatures on the island have increased, more of that precipitation is falling as rain. As a result, most of the snowpack has melted by mid-summer, creating a longer drought season. This is a problem not only for the skiers, but also for all the plants, animals, and people who rely on the snowmelt for water. As a result, the ski resort returns as available space but another area on island is now too dry for the Kiwi grass to grow and becomes unavailable as habitat (making little net difference in available Kiwi grass habitat).
13) **Round 9**: The Rumples, a small ground-dwelling hairless rodent, also live on Kiwi Island. They dig tunnels in the soil to live in. Kiwis make their nests in recently abandoned Rumple tunnels. The hotter, drier days have been hard for the Rumples, because their skin must remain moist, and thus their population has declined. The Kiwis now have fewer places to safely raise babies. In this round, half the chaperones become Rumples (the other half remain drivers) and walk around making high pitched squeaking noises and using their fingers as whiskers on their faces. All

Kiwis must find one Rumple before the end of the game and 2-hand tag them in order to have a nest to raise a successful baby for the next generation. If they don't, they die and become a Woogie.

14) **Round 10**: A large storm hits the island. Storms of this sort used to be rare in these cooler waters, but the water temperature around the island has increased by 2° C, and that is enough to create powerful tropical storms. One side of the island was hit particularly hard, and it will take several years for the habitat, including the Kiwi grass to re-grow, as much of the soil was washed away. This area is taken out of the game.
15) **Round 11**: The number of visitors to Kiwi Island has doubled in the past two years. These visitors love to watch the Kiwis and take pictures. The problem is that Kiwis are very shy and according to scientists, they will not mate or feed their young if they have seen a person in the last four hours. Therefore fewer Kiwis are being born. To represent this in the game, say that Woogies with birthdays from January through June cannot turn into Kiwis even if they are hit.
16) Other optional round additions include:
    a. A miner who is backed by industry money and lobbying
    b. The building of an educational institute
    c. Native use issues (perhaps sustainably gathering grasses)
17) Have students get their journals, pencil, water, and come into the middle of the island. Show the students the population tally on the whiteboard, and have students create a graph depicting these populations and their changes. For younger students you may draw a graph on another white board as they are doing it in their journals, labeling the X-axis as rounds (or time) and the Y-axis as population numbers. In two colors, plot the population numbers of the Kiwis and Woogies over the course of the rounds. The students' need for help and demonstration will vary based on age and experience. After drawing the graph, ask students why the graph looks the way it does, what factors affected the changes in population growth. Do we see some of these patterns in natural populations? What is not realistic about this?

Wrap-Up

After you finish graphing, follow with a discussion about this activity using the questions below. The questions will vary based on the age of the students and the rounds you selected from the above choices. For younger students, this discussion will be focused on the different factors that affect protected areas and the different choices we make when managing land. For older students, this conversation should focus on the interaction between climate change and other pressures or human impacts that natural systems face.

Discussion Questions

- What was realistic and what was unrealistic about this game?
- What was missing from this system (the grass, carrying capacity of the land)
- Were these issues realistic for your park?
- How did the various development projects affect the park?
- What are ways that climate change affected this ecosystem?
- How do you think climate change would have affected the people, like Joe Camper, Mr. and Mrs. Highbrow, and Steve Skibum?
- How did development issues and climate change issues interact in this game? Did they make each other worse or alleviate each other?
- Which of the issues mentioned in this game affect the area that you are from? The world at large?
- How much development should there be in national parks? Should there be ski resorts? Golf courses? Fancy hotels? Campgrounds? Roads? (Yosemite National Park has all of these, yet it is still 95% designated wilderness.)

In the Classroom

This activity is a great week-closing lesson in which all aspects of outdoor education curriculum are touched on, including teamwork, ecological principles, park management, and human impacts on ecosystems. A great classroom extension would be to look at the map of federally protected lands (see “Check this Out” section below) and examine the ones near you. Divide students into groups and have them each research a different area in your region that has a different type of land designation (National Park, Forest Service, Bureau of Land Management, Wilderness, etc.). Students can present to the class what their area is like, including what is and isn’t allowed on that public land.

Variations

Variations on this lesson can be created by choosing different “Round” options from the list above. This activity can easily focus more on direct human impact and development or more on climate change. With younger students, you may only want to choose a few of the rounds, where as with older students you can move more quickly through the complex rounds.

This activity was modified from a lesson done by Dave Dahler, adapted from a write-up by Lissie Kretsch, 09/23/2008, and based on lessons by many Yosemite Institute Instructors.

Park Issue Debate: Hetch-Hetchy

Educator Summary

The Hetch-Hetchy debate is an activity that can be modified for debating land and resource use in any managed natural area to help students practice critical thinking skills and articulate ideas about a controversial management issue. It was created for an indoor, evening, or classroom setting, but could also be done outdoors in nice weather.

This activity is designed to show students why different interest groups may have different opinions on an issue and the complexities of arriving at best use practices. Although the Hetch-Hetchy issue is unique to Yosemite, debates over how to manage national parks continue in almost every park today. Questions that arise in many national parks may include, among others: Should we build a road? Should we increase or decrease access or development? Should we allow pack animals? Should we designate parts of the park as wilderness? Should we charge more at the entrance gate to pay for more rangers?

You can take this activity one step farther by choosing a topic related to climate change, or asking how the issue you are debating is affected by climate change. For example, the Hetch-Hetchy debate began in the early 1900's, but now the issue of water resources is even more pressing for California and will likely be significantly affected by climate change as the snowpack in the Sierra Nevada Mountains changes (see hydrology section). By using the structure outlined below, this activity could be used by students to debate any local resource management issue, past or present. The skills cultivated in this activity are essential for students to be able, eventually, to contribute to the complex issue of climate change.

Key Concepts

- Management solutions must take into account the interests of many stakeholders with varied interests and opinions.

- Critical thinking skills, convincing articulation of a given position, ability to understand and address opposing views, and ability to compromise are important skills to have in advocating for an interest group and creating solutions to environmental issues.

Grade Level: 6 - 12

Materials:

- Costumes for each stakeholder group to "get into character."
- Packets for each stakeholder group, including the following:
    - Name tags for stakeholder groups
    - Information cards outlining the position of each stakeholder group

- A question sheet to help students highlight important points
- Presentation on the topic to be given by educator (could be a PowerPoint).

Time: 1 hr

Introduction

Put the students in groups depending on the number of stakeholder groups. Three to five kids per group is ideal. Explain to students that they are going to learn about an important current or historical debate. Then give a presentation that introduces the topic, the main issues, and the various stakeholders. Stop before discussing where the issue stands today or how the issue has been/is being resolved. A PowerPoint with lots of visuals works well.

Procedure

1) Tell students to open their packets and find out which stakeholders they are going to represent. Inside they will find the information on their group. Give them 10 minutes (or more, depending on their needs) to read the information and start discussing it, using the question sheet as a guide. They should write down answers to the questions on the sheet. During this time they should be preparing to present their position convincingly to the rest of the group.

2) Tell students to choose two students to come up and present. These students should put on the costumes and name tags.

3) One at a time, each pair of students presents the viewpoint of their group of stakeholders (1-2 minutes), and then other groups get a chance to ask questions. Encourage students to use the questions as a way to demonstrate holes in the groups' arguments (or to support them, if they are on the same side). You may or may not want to do "closing arguments."

4) After all groups have presented, have students "take off" their stakeholder positions and think about how they feel about the issue after what they have learned. If it is appropriate for the subject, take a vote of the students' true opinions.

Wrap-up

Fill the students in on where the debate stands currently. If it is an historical debate, such as the damming of the Hetch-Hetchy valley, tell students what was decided and where the issue stands today. Ask what they think should be done now that this action has been taken. What are the issues that any new action would bring up?

Discussion Questions

Examples of questions that would go on the "question sheet" given to each group:

- Would the creation of a dam in Hetch-Hetchy valley help or hurt your group? Are you for or against it?

- Come up with a slogan for your group. (ex. Engineers for clean solutions, or Farmers + Free Rivers = Food for Americans)

- Write down three reasons why your group supports or does not support the construction of a dam in Hetch-Hetchy valley.

- Why does your group feel this way? Why is this issue important to you?

- What might other groups criticize about your argument? How would you respond?

- Come up with one question you could ask each of the other groups that will highlight a weakness or strength in their position.

Diving In

Many of the activities in this section debate the extent to which land should be protected and the idea of "wilderness." An exploration into the Wilderness Act is a way to go deeper into this context and explore the different designations that are given to national parks.

The Wilderness Act was signed into law in 1964 "to establish a National Wilderness Preservation System for the permanent good of the whole people . . . ." It is well known for poetically defining wilderness, stating:

> "A wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the earth and community of life are untrammeled by man, where man himself is a visitor who does not remain."

The Wilderness Act has been interpreted to prohibit the following from the areas it protects: all motorized or mechanical vehicles or equipment (including bikes), roads, development, logging, mining, and oil and gas drilling. The Wilderness Act provides an added layer of protection to public lands run by any of several different public agencies including the National Park Service.

In the original act, just over nine million acres of land were given this designation. Today, the wilderness system includes over 109 million acres of wilderness, or more than 170,000 square miles. On March 30, 2009, President Barack Obama signed into law the Omnibus Public Land Management Act, which designated an additional two million acres in nine states as wilderness, representing the largest expansion of wilderness lands in over 25 years.

About 41% of wilderness lands are under the jurisdiction of the National Park Service, the most of any agency. 56% of National Park Service land is designated wilderness.

Sources

www.wilderness.net

The Wilderness Society, www.wilderness.org

Climate Change and Our National Parks

This final chapter is written as one lesson plan. The activity explores eight national parks from across the country. Students will be asked to think about global climate change and the potential impacts to both the ecosystem and the surrounding communities of that area.

Educator Summary

The National Park Service mission statement charges the organization with conserving the scenery, including the natural and the historic, for the continuing enjoyment "as will leave them unimpaired" for future generations. The system includes habitat protection for 378 threatened or endangered species, 100 million museum items, 27,000 historic and prehistoric structures, and 17,000 miles of trails. This is a difficult task in the best of times. With a changing climate comes an increase in the challenge. The list of changes our planet is likely to undergo with increasing carbon dioxide in our atmosphere is daunting and includes rising sea levels, increasing air and water temperatures, changes in precipitation, increasing evaporation, and shorter, milder winters.

Key Concepts

- Students will learn about the ecosystems and climate of national parks across the country.
- Students will predict how climate change will impact these national parks.
- Students will predict how climate change will impact the plants and animals protected by these national parks.

Grade Level: 6^{th} – 8^{th}

Materials: National Park cards and questions, large paper and markers

Time: 1 hour

Introduction

Across the country, there are nearly 400 places preserved and protected by the National Park Service. They range from temperate rain forests to southwestern deserts, from canyons to mountains, from historic homes to mangrove forests. As a nation, we have decided that these places shall remain as they are for future generations. National parks have rules to limit the impact that people can have on these treasures. However, there are some human impacts that the Park Service can't control. A changing climate will impact the national parks. Rising sea levels, changing precipitations patterns, worsening storms, and increasing air temperatures will occur inside national parks just as they occur outside. National parks across the country will be impacted in different ways. The plant and animal communities protected by our parks will have to adapt or they will not be able to survive through some of these changes. Species already on the edge of extinction may be pushed over that line; others will thrive as their habitats expand. In this activity, students will learn more about one national park and brainstorm how a changing climate may affect the plants, animals, and people of that place.

Procedure

1) Pass out the maps of the United States National Parks (These can be found at: http://www.pueblo.gsa.gov/cic_text/travel/parkserv/NPSmap2.pdf.)

2) Ask the students to think about the different regions of the United States. List these on the white board with the region as the heading of a column. Fill the columns with characteristics of these regions (For example, Desert Southwest: dry, cactus, sagebrush, hot, monsoon season, rivers can dry up, ancient structures, etc.)

3) Make sure students are familiar with the following terms, which will be used throughout this activity: **invasive** species versus **non-native** species versus **native** species, **sensitive** species versus **threatened** species versus **endangered** species, **endemic** species, and **biodiversity**.

4) Divide students into small groups of up to five.

5) Give each group one of the National Park Cards and one National Parks and Climate Change Questions sheet. Do not pass out the Climate Change in the Parks cards yet.

6) Using the information on the card and the map, the group will fill in the information on the question sheet.

7) Now that the groups have made their predictions, hand out the Climate Change in the Parks cards. The groups may use this information to “check” their predictions. Remember that the information on these cards is also based on predictions.

8) Ask the groups to prepare a presentation based on the National Park card and the Questions card.

Wrap-Up

National parks across the country are facing a variety of challenges that will come with a changing climate. As a group, list the common impacts that came up again and again in these presentations. List the impacts that only affected one or two of the parks. Now look at the region where these parks are located. Climate change is not only coming to national parks. The whole region where this park is located will feel some, if not all, of these changes.

Discussion Questions

- Are all of the impacts of climate change “bad” in all places?
- What other sorts of information would have been helpful in making predictions?
- Are all of these parks facing the same level of threat from climate change?
- What are some the variables that may cause the rate of climate change to speed up or slow down?

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Bandelier National Monument

(New Mexico)

About the Park

Bandelier National Monument is in northern New Mexico, on the slopes of the Jemez Mountains and at the edge of the Southern Colorado Plateau. The elevation ranges from a little over 5,000 feet along the Rio Grande to over 10,000 feet at the tops of its highest mountains. This big change in elevation over a relatively short distance provides many different types of habitat found only in Northern New Mexico. The variety of plants and animals in the area as well as a year-round supply of water in what can be a dry region accounts for Bandelier's long history of human occupation, which extends back for over 10,000 years.

Photo: Sally King

Bandelier National Monument

(New Mexico)

How will Climate Change affect this park? Increased temperatures will make the area more susceptible to drought and fires. Organisms at Bandelier are dependent upon the water cycle, not only in terms of the amount of flow, but also in terms of timing and frequency. If there is not a sufficient amount of rainfall during the year to fill the underground aquifers, the springs in the park will not provide moisture during droughts. Plant species in mountainous, arid, and semi-arid areas are slow-growing and not as able to adapt quickly to changes in precipitation or to grow back quickly after fires. This creates an opportunity for invasive plants and animals to move in and stay, altering the ecosystem.

What is the National Park Service doing? Bandelier is taking part in a research program that is trying to predict the responses of mountain ecosystems to climate change and come up with appropriate management strategies. In addition, park staff members have created and are following a plan to reduce greenhouse gas emissions in the park. The plan includes installing recycling bins throughout the park, using energy-efficient light bulbs and fixtures,

Photo: Sally King

The Everglades National Park
(Florida)

About the Park

The Everglades is North America's only subtropical preserve, with 137 miles of coastline. With 1.5 million acres protected, it is the third largest national park in the continental US (behind Death Valley and Yellowstone). It is an extremely low-lying area: two-thirds of the park lies less than three feet above sea level, and it has a natural maximum elevation of eight feet. Nine distinct habitat types have been identified in this warm, wet area including uncommon habitats such as mangroves, pinelands, cypress forests, and freshwater sloughs. These diverse habitats are home to over 1,000 species of plants, 20% of which are non-native. The Everglades' climate makes it well suited for many invasive plants and animals, such as the Burmese Python, one of the largest snake species in the world. The Everglades are also home to a wide variety of native wildlife, including many endemic and endangered species, such as the Manatee and the Florida Panther. Over 360 species of birds have been recorded in the park, and the list continues to grow.

The Everglades is a highly disturbed system. Much of this area was drained by people in the early 1900's to make this swampy land more suitable for farming and development. The Everglades National Park was established in 1947 to conserve the natural landscape and prevent further degradation of its land, plants, and animals. To this day, the hydrology of the area remains largely disturbed, although efforts are continually being made to restore this area to as natural a state as possible. The large and fast growing human population in Southern Florida also puts pressure on this area, especially in regards to water resources.

Great Egret in cypress swamp. Photo: Rodney Cammauf, National Park Service

The Everglades National Park
(Florida)

How will climate change affect this park? Sea-level rise (predicted by IPCC 2007 report) could have significant impacts on this low-lying park. Park researchers report that sea level on Florida's southern coast has risen nine inches in the past century, six times faster than the per-century rate over the previous 2,400 years. Sea-level rise could lead to inundation and dramatic shifting of fragile and rare ecosystems, such as the pineland forest. Species that depend on these ecosystems could face habitat loss. For example, the endangered Cape Sable Seaside Sparrow, which depends on shallow marshes, would be further threatened if these shallow marshes became deeper. Erosion and salt water intrusion are also concerns associated with sea level rise. In addition to the extent of sea level rise, the rate of rise is of concern because mangroves, which protect much of the Everglades coastline from erosion and provide habitat for many species, may not be able to move upland as fast as the sea rises. Lastly, climate change may cause a rise in water temperatures in this area. Some scientists think that this could lead to more, and stronger, hurricanes. Warmer waters also threaten many marine animals including corals and some fish.

What is the National Park Service doing? It may be hard for the Everglades ecosystems to be resilient in the face of multiple stressors. Therefore, park managers are doing things to manage the risks that can be controlled, such as human damage from boats and hydrology restoration efforts, so that the ecosystems are at their best when they face the challenges of climate change. The park is making steps to curb its emissions by reducing the number and size of staff vehicles, both marine and automotive. The Everglades has also committed to increasing climate change education in the park “with a goal of providing 100% of visitors to the park with the opportunity to be exposed to climate change issues.”

Photo: National Park Service.

Gates of the Arctic National Park

(Alaska)

About the Park

There are no trails, roads, campgrounds or facilities in this expansive wilderness in Northern Alaska. At 13,238 square miles, it is the second largest National Park in the U.S. and lies mostly in the Brooks Mountain Range, an alpine arctic mountain range. Located entirely above the Arctic Circle, come June, this is truly the land of the midnight sun. The habitat is mostly tundra, which is dotted with many wildflowers in the warmer months. Most of this national park is in the permafrost zone, meaning that the land underfoot is permanently frozen to varying depths. Here you can see a variety of wildlife many of which are rarely seen elsewhere, such as grizzly bears, moose, caribou, wolves, musk oxen, and arctic ground squirrels. Thousands of caribou migrate annually through this region in search of dense lichens to eat. Additionally, 145 species of birds have been recorded in the park, many of which are long distance migrants that travel vast distances each summer to reach this extremely productive environment fueled by constant sunlight. The harsh climate in this region keeps out many land predators, invasive species, and pests. Gates of the Arctic is unique for a U.S. national park in that some 1,500 people reside in 10 small communities in the park's "resident subsistence zone" where they rely on the park’s natural resources for survival.

Photo: Don Pendergrast, National Park Service

Gates of the Arctic National Park

(Alaska)

How will climate change affect this park? Over the past 50 years, average temperatures in Alaska have risen twice as fast as temperatures in the rest of the United States, according the seminal report released in June, 2009 by the United States Global Change Research Program. Average summer temperatures have risen 3.4° Fahrenheit, while winter temperatures have risen 6.3° Fahrenheit. This is impacting the state and its national parks in many ways. Gates of the Arctic National Park lies entirely in the permafrost zone, meaning that the ground beneath the tundra and mountains is permanently frozen. Parts of central Alaska previously within the permafrost zone have begun to melt, changing the earth's surface above it dramatically, altering ecosystems and hydrology, and causing trees to tilt, buildings to crack, and roadways to buckle. This thawing could move into the Brooks Range and Gates of the Arctic if warming trends continue. Longer summers and higher temperatures are causing drier conditions and fewer lakes, altering important breeding habitats for birds and other animals. This also may lead to an increase in wildfires. Additionally, changes in seasonal timing may have many effects on wildlife, such as the caribou that make long migrations every year and may now find some rivers impassable due to increased spring run-off.

What is the National Park Service doing? The park service is in the process of creating an amendment to their 1986 General Management Plan. The park service attributes the need for this amendment to conditions that have changed since the plan's original creation. The park highlighted climate change as one of three major emergent issues since 1986. Additionally, the Dalton Highway, which runs along the park's eastern boarder only five miles outside the park boundary, has opened to the public, making this area accessible by road for the first time.

Photos: National Park Service Collection

Great Smoky Mountains National Park

(Tennessee/ North Carolina)

About the Park

The Smokies, also known as the "Salamander Capital of the World," are known for their biodiversity. With an estimated 90,000 species of plants and animals living in 800 square miles, no other area of equal size in a temperate climate has a comparable numbers of species. The Smokies, a part of the Appalachian Mountain chain, are some of the oldest mountains in the entire world. Their elevations range from 875 feet to 6,645 feet above sea level, providing unique and diverse ecosystems. The forest diversity seen walking from the bottom of a mountain to the top is often compared to the forest habitats seen traveling from Georgia to Maine.

Waterfalls, some of the oldest forests on the east coast, around 900 miles of trails, and amazing views make the Great Smoky Mountains National Park the most visited national park in the world, with around 9 million visitors a year. The park is one of the largest wilderness tracts in the eastern US, providing habitat for black bears, river otters, elk, 200 species of birds, and countless endangered species.

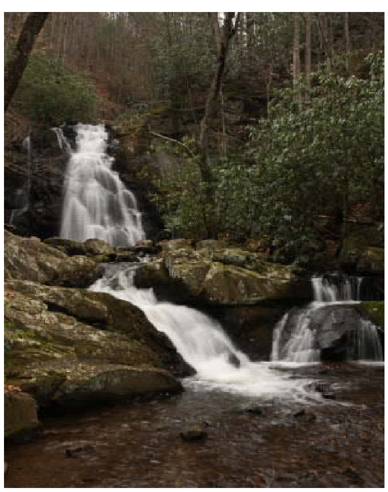
The Smokies are known for their mist and blue haze. Photo: Ken Voorhis

Great Smoky Mountains National Park

(Tennessee/ North Carolina)

How will climate change affect this park? Unfortunately, the Smokies have some of the worst air quality of any national park. In recent years, mountain views have decreased 80% due to the haze from air pollution. Sometimes, the air quality is so bad that there are "ozone alert days," where strenuous activity, such as hiking, is not recommended. As average temperatures in the southeastern US increase, forest species have to adjust and adapt. Species unique to the park's high elevation forest, such as the Fraser fir, red spruce, and northern flying squirrel, will struggle to find suitable habitat. The Smokies can expect to lose 17% of their mammalian species due to shifts in distribution ranges. As temperatures increase, the cool mountain streams will warm, affecting the park's cold-water fish, such as brook trout. The Smokies receive an average of 55 inches (at lower elevations) to 85 inches (at higher elevations) of rainfall a year. Scientists believe that climate change in the southeastern US will lead to an increase in yearly rainfall. Due to the Smokies' steep slopes and plentiful rain, landslides are fairly common and might increase with this increased rainfall. Increased levels of carbon dioxide may, however, increase forest growth in the Smokies.

What is the National Park Service doing? Park rangers, researchers, and volunteers are participating in an immense project called the All Taxa Biodiversity Inventory. The goal is to inventory every living species in the park to better understand and describe the biodiversity of the Smokies. Without this inventory, we will not know what changes, if any, occur in species population distribution due to increased temperatures. In addition, a 70-mile section of the Appalachian Trail runs through the park. The NPS helps maintain this trail, providing a 2,175 mile corridor of protection for species. The Smokies Interpretive Rangers have also included climate change into their programs, hoping to educate park visitors on the affects they have on the environment.



Spruce Flats Falls. Photo: Les McGlasson

Hawai’i Volcanoes National Park

(Hawai’i)

About the Park

Hawai’i Volcanoes National Park sits on the southeastern edge of the youngest and largest island in Hawai’i and is home to many diverse plants and animals. It is famous for its volcanoes, but also has many different ecosystems, including coastlines, rainforests, woodlands, and lowlands. The Park is one of the few remaining natural areas in Hawaii that protects contiguous habitat from sea to summit. The islands are distant from large land masses, so the native plants and animals have not been influenced by neighboring species. Over 90% of the native terrestrial flora and fauna in Hawai'i are found only in the Hawaiian Islands.

Holei Sea Arch Photo: NPS Photo

Hawai'i Volcanoes National Park

(Hawai'i)

How will climate change affect this park? Changes in temperature and rainfall will affect many of the unique plant and animal species that have adapted to specific niches within their ecosystems. For organisms that live in high alpine zones, there is no higher and cooler place for them to move as the temperature rises. Changes in precipitation will affect native birds' ability to breed and handle disease. As the sea level rises, areas of cultural importance and breeding grounds for endangered species will become covered with water. As the ocean increases in acidity, coral organisms will not be able to create the skeletons they use to build coral reefs.

What is the National Park Service doing? Scientists at Hawai'i Volcanoes National Park are studying coral reefs, native birds, and endangered species such as the Hawaiian Monk Seal to determine what affects changes in temperatures will have upon them. They are also working with native Hawaiian elders to determine what changes have already occurred in the island habitats and to make a list of culturally important places and plants that will be affected. The park has taken measures to reduce its carbon footprint by adding solar panels to park buildings and testing a hydrogen hybrid shuttle system. It is an active member of the climate Friendly Parks program, with staff members taking measures to reduce their personal energy consumption. In addition, the Park is working to educate its staff and visitors about climate change and what they can do to help.

Photo: National Park Service

Indiana Dunes National Lakeshore

(Indiana)

About the Lakeshore

Indiana Dunes is located on the shores of Lake Michigan and encompasses 15,000 acres stretching along 15 miles of shoreline between the cities of Gary and Michigan City in Indiana. The Lakeshore not only protects the beaches along Lake Michigan but expands inland to include dunes, oak savannas, swamps, bogs, marshes, prairies, rivers, and forests. Moving inland from the current shoreline, the lakeshore encompasses three ancient shorelines that developed as the Great Lakes were formed by melting glaciers. The oldest two dune complexes have developed into stable oak forests. The third, younger dune complex and the current shoreline are still changing with many stages of plant succession visible including open beaches, grass covered ridges, woody shrub vegetation, pine-forests, and oak-forests. This wide range of ecosystems provides for one of the most biologically diverse areas in the national park system, with 1,100 flowering plants and ferns.

The wide range of plant communities provides for a diverse wildlife population as well. Migratory birds in particular make use of the protective cover of the dunes as a resting and feeding spot. Over 350 species of birds have been observed at Indiana Dunes. In the fall, birds migrate south along the edges of Lake Michigan, converging at the southerly tip of the lake, where Indiana Dunes is located.

Waves at Lake View. Photo: National Park Service Collection

Indiana Dunes National Lakeshore

(Indiana)

How will climate change affect this Lakeshore? Water levels in the Great Lakes are likely to fall because of the decreased snow and increased evaporation that are products of higher air temperatures. The wetlands that fill the valleys of Indiana Dunes will begin to dry up, decreasing the biodiversity of the area and the value of the area to migrating birds. Precipitation is more likely to come in flooding downpours from heavy storms. Increased temperatures will warm the waters of Lake Michigan, reducing coldwater fish like salmon and trout. Ground-level ozone, dangerous to people, plants, and wildlife will increase with warmer air temperatures.

What is the National Park Service doing? Indiana Dunes has planned several projects to reduce the carbon footprint of the facilities. Solar-powered lighting will be installed throughout the park as will two new “green” roofs on administrative buildings. Green roofs are planted with vegetation and will absorb rainwater, provide insulation, and create a potential habitat for wildlife. The NPS is partnering with other federal agencies and local entities to manage invasive species and will begin a study of shoreline erosion. The Park Service has also developed an extensive monitoring project to detect changes in the breeding bird populations that make use of Indiana Dunes. The extensive wetlands of the lakeshore have been severely impacted by development in the eastern half of the park, but the park service is in the process of restoring portions of an extensive wetland complex called the Great Marsh, south of the primary dunes in the eastern half of the park. Because wetlands naturally filter contaminated water, restoring the Great Marsh will also help to improve the area's water quality. In addition, by plugging ditches, restoring the area's hydrology, removing invasive plants, and planting native species, the national lakeshore is re-creating a diverse and beautiful ecosystem.

Lake View beach with paper mills in background. Photo: Christopher Light, National Park Service

North Cascades National Park

(Washington)

About the Park

The North Cascades National Park Complex includes both a National Park and two recreation areas. It lies in the northwestern corner of the US with Canada as its northern border. It covers both the eastern and western flanks of the North Cascades Mountains, lying across the Cascades Crest, which runs north to south through the park. The park is famous for having more than 300 glaciers and diverse mountain ecosystems, which include large areas of subalpine and alpine habitat. It is one of the snowiest places on earth, and is more glaciated than anywhere in the continental United States. A large portion of the park is a designated Wilderness area. There are three hydropower dams in the recreation areas.

Photo: Megan McGinty

North Cascades National Park

(Washington)

How will climate change affect this park? The 300 glaciers in North Cascades National Park are disappearing; park scientists report that many of the glaciers have receded noticeably during the last 150 years, resulting in a loss of 40% of the park's ice cover, a pattern which closely matches the warming trend of climate change. Melting glaciers will change soil and vegetation patterns and release old pollutants, long stored in the ice and snow, into fresh glacial lakes and streams. High elevation ecosystems are sensitive and rely on a snowpack deep enough to insulate plants and animals in the winter; with the temperature increases associated with climate change, this snow pack is threatened. In addition, snowmelt is an importance source of water for alpine ecosystems in the summer. The snow that falls in the higher elevations in the winter supplies the glaciers with a reservoir of ice that feeds the rivers in the summer, keeping the rivers cool and deep enough for salmon. As the glaciers melt, this important runoff will decrease. Longer summers and shorter winters, which are predicated to come along with climate change, will also contribute to more frequent forest fires in the park. In addition, because of habitat loss, which may be linked to climate change, species native to the Cascades such as the gray wolf, grizzly bear, fisher, wolverine, and Townsend's big-eared bat have become threatened.

What is the National Park Service doing? The park service has been monitoring glaciers in the North Cascades since 1993 to understand if the glaciers are melting and if so, how quickly. In addition, they are making an inventory of all the plant and animal species in the park and mapping where they are found in order to keep track of changes. Because North Cascades National Park is one of the best places in the US to see glaciers, park staff members are working on educating themselves and park visitors about the connection between glaciers and climate change. They are also looking at ways to reduce their use of motorized vehicles, and, when they do need to drive, to use more efficient vehicles.

Photo: Christian Martin

Yosemite National Park

(California)

About the Park

Yosemite is nearly 1,200 square miles in size and is located in the Sierra Nevada Mountain Range in California. It is perhaps best known for its unique geologic features such as granite domes like Half Dome, towering cliffs like El Capitan, dramatic canyons like Tenaya Canyon, and abundant waterfalls like Yosemite Falls. Yosemite has a Mediterranean climate, which means it has hot, dry summers and cool, wet winters, with most of the precipitation in the park falling as snow and melting gradually over the spring and summer months. Yosemite has a large elevation gradient, from about 2,000 ft. in the foothills, up to Mt. Lyell, the highest peak in Yosemite, at 13,114 ft. As one travels higher up in elevation, the climate gets colder, meaning that Yosemite has a large range of climates, from areas that rarely get any snow to areas that get many hundreds of inches annually. Because of this, Yosemite has a wide range of habitat types, or life zones, and a resulting variety of flora, including oak woodlands, coniferous forests, and alpine habitats, and fauna, including black bears, mule deer, coyotes, and bobcats. At higher elevations, you can see rarer animals such as yellow-bellied marmots, golden-mantled ground squirrels, pikas, and gray-crowned rosy finches. Yosemite is also home to four species of endemic amphibians, some of which are threatened. These populations face pressures such as invasive species, high visitation and disturbance, disease, and wildfires. Wildfires are a natural part of the ecosystems in Yosemite. Yosemite is also one of the most visited national parks, with close to 4 million visitors per year. As a result, park management must deal with issues regarding air and noise pollution.

Photo: National Park Service Collection

Yosemite National Park
(California)

How will climate change affect this park? Because much of Yosemite is high in elevation, most of the winter precipitation falls as snow. Rising temperatures could change much of this snow to rain, as the climate here often hovers around the freezing point. This could be problematic for the rest of the dry, heavily populated state of California,which relies on the slow melt of the Sierra Nevada snowpack to provide year-round water. In fact, 50% of the water used in California originally falls in the Sierra Nevada Mountains. Because of its wide elevation gradient, Yosemite also supports many different life zones and associated species. A changing climate could shift these zones, and there is potential for high alpine species, like the gray-crowned rosy finch and the pika, to get pushed out. Some species, like the giant sequoias, would have a hard time adapting or moving under changing environmental conditions because of their long life cycle. Additionally, warmer, dryer summers could mean a higher potential for large wild fires. Because so many species here already experience other pressures or disturbances, there is concern that even small shifts in climate could be hard for them to deal with.

What is the National Park Service doing? To deal with high levels of visitation, the Park Service has established a system of free hybrid shuttle buses around Yosemite Valley. Yosemite also has installed solar panels on some buildings and has a program called YES (Yosemite Environmental System) that identifies environmental issues in the park, including greenhouse gas emissions. Because of the number of visitors, there is great potential for education and outreach in Yosemite. Therefore, the interpretation division has taken on climate change education as a main focus for 2010.

Photo: National Park Service Collection