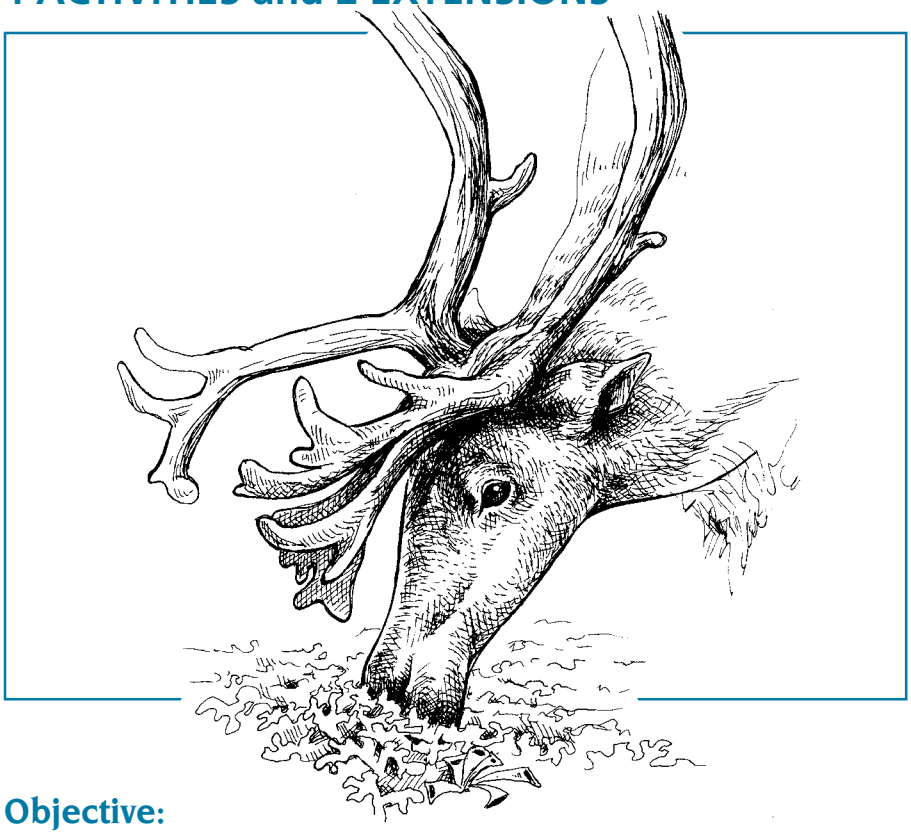
Tundra Puzzlers

4 ACTIVITIES and 2 EXTENSIONS



Section 5
TUNDRA ACTIVITIES

Grade Level: 8-12
State Standards: S A-14, S A-15, Geo E-5
Subjects: Science, language arts
Skills: Synthesizing, inferring, predicting,reading,oral communication
Duration: 50 minutes
Group Size: Small or individuals
Setting: Indoors
Vocabulary: Acidic, active layer, alga/algae, alkaline, arctic haze, chlorophyll, fungus/ fungi, half-life, harvested, home ranges, mortality, omnivores, percolate, permafrost, photosynthesize, radioactive isotopecesium-137,specific tolerances, symbiotic, survival rates, tundra

Objective:

Students will recognize that human activities affect tundra ecosystems.

Teaching Strategy:

Students use the story-problem information in the 4 Tundra Puzzlers to examine how certain human activities can have unexpected and long-lasting effects on tundra ecosystems.

Materials:

Copies of "Tundra Puzzlers" (*following pages*) for each student ["What Ecologists Have Learned" *follow each puzzlers*].

Background:

See INSIGHTS *Section* 5, *Human Impacts*, and *Section* 2, *Topography and Soil*, "*Permafrost Features*," and article on thawing.

Procedure:

1. Organize students into small teams or as individuals. Hand out the puzzlers.

2. Explain that students are to use the facts provided to figure out a solution to the puzzler. To solve each puzzler, students will need to do the following:
(a) Read the information carefully.
(b) Look for connections in the information.
(c) Apply their knowledge of tundra ecology.
(d) Find and define all unknown words.
(e) Explain and defend their reasoning.
List these steps on the board.

3. Students read their puzzlers and facts and develop their own solutions.

4. Review each puzzler with the class. Ask those who worked on each puzzler to explain the puzzle and their solution or prediction. Discuss the puzzler with the whole class.

5. Read aloud the scientists' solutions. Compare them with the students' solutions.

Evaluation:

Students write a description of some of the effects of human activities on tundra ecosystems.

EXTENSION:

A. **Write pair of stories or plays.** Students write or act out 2 stories about changes to tundra as people settle into the area. In the first story, students focus on human actions where there is a lack of concern or understanding about the tundra ecosystem. In this story, short-term human needs take precedence over the health of the ecosystem.

In the second story, long-term health of the ecosystem is viewed in relation to human health. The community plans for the long-term health of both people and the ecosystem as a whole.

Follow these stories or plays with a discussion about responsible human action toward wildlife and the need for information and understanding about ecosystems.

B. **Compare ancient and modern impacts.** Students study the historic and traditional lifestyle of nomadic tundra peoples and the impact that lifestyle had on the tundra. Students then look at modern life in tundra communities and identify decisions and actions that can lessen harmful impacts on the tundra.

Curriculum Connections:

(See appendix for full citations)

Books:

Acid Rain (Edmonds)

Acid Rain (Patten)

Food Chains (Silverstein)

Into Thin Air: the Problem of Air Pollution (Kidd)

Vanishing Ozone: Protecting Earth from Ultraviolet Radiation (Pringle)

Food Chains (Silverstein)

Media:

Acid Rain (Video) (Gr.5-12)

Acid Rain, the Invisible Threat (Video) (Gr. 6-12)

Websites:

Alaska Science Forum
<www.gi.alaska.edu/ScienceForum

Alaska Statewide Databases <sled.alaska.edu>

Staff-written Alaska newspaper articles: *Anchorage Daily News* Archives <www.adnsearch.com> or *Fairbanks Daily News Miner* <www.newsminer.com>

Teacher Resources:

(See appendix)

Tundra Puzzler 1

TUNDRA AND PERMAFROST – ICY BALANCE

Background Information

• **Permafrost** – *perennially frozen soil* – underlies most of the **lowland tundra** in Alaska. Permafrost may be from 2 inches to several feet below the surface, depending on local environmental conditions. Generally, permafrost is nearer the surface on north-facing slopes and in sites where the soil is insulated by vegetation.

• Mosses, **lichens**, and flowering plants insulate the permafrost and help prevent thawing. They die when they are repeatedly crushed or trampled. They grow very slowly because of cold temperatures, short growing seasons, and the scarcity of minerals in tundra soils.

• All plants have **specific tolerances** for soil moisture. Some species grow only on dry soils, while others grow only on wet soils.

• Much of the lowland tundra in northern Alaska receives less than 5 inches (12.7 centimeters) of precipitation per year. This is equivalent to the amount of precipitation in a desert.

• Water from rain and melting snow drains into low-lying spots. Except for stream drainage, the annual precipitation in lowland tundra remains on top of the permafrost because water cannot drain through frozen soil.

• This layer of soil on top of permafrost is called the **active layer** because it thaws and refreezes each year.

• Water expands when it freezes, so that wet soil that is frozen takes up more room than does thawed wet soil.

• Water is an excellent conductor of heat energy. If you expose a pan of soil and a pan of water to heat, the water gets warmer faster and stay warmer longer. It absorbs and retains more heat from sunlight than the soil does.

THE PUZZLE

Based on the information given and your understanding of ecology, what changes in the tundra would you expect to occur after a large track vehicle was driven across the tundra?

What changes might you expect if reindeer or caribou were confined by fences, roads, or other obstructions to a small area of tundra for several days,? What would be the effects of a hiking trail across permafrost tundra?

If Alaska's permafrost melted, what would happen to buildings, pipelines, and highways?

Tundra Puzzler 1

TUNDRA AND PERMAFROST – ICY BALANCE

What Ecologists Have Learned

Disturbance of tundra vegetation by vehicle traffic or by repeated trampling by reindeer, caribou, or humans will kill plants and lichens. This removes a layer of insulation from the soil surface. As a result, the exposed soil thaws to a greater depth than do surrounding soils.

The thawed soil takes up less space than the frozen soil did originally; thus the thawed soil in the site slumps or subsides.

Water drains into the low spots created by the slumping. Although water may percolate through the active layer, it cannot seep through the underlying and surrounding permafrost.

The collected water absorbs heat from sunlight, so that underlying and surrounding permafrost is further melted.

When winter returns, the collected water and water-logged soil freeze and expand. The pressure of the expanding ice forces the surrounding soil out and upward, thus enlarging the low spot and creating mounds in the surrounding soils.

In spring, when the active layer thaws again, the water-logged soil in the site once more subsides and becomes a collecting pool.

Over years, this repeated freezing and thawing enlarges the low spots originally caused by a disturbance of the vegetation. Ultimately, a large area of formerly dry soil is converted to low-lying, wet or submerged soil.

The plants that previously grew on the spot cannot survive in the wet soil. They die and cannot recolonize the site. Although plants adapted to wet soil may invade, their colonization of the area is slow (due mainly to slow rates of plant growth in tundra environments).

Thus, as a result of the interconnections between vegetation, water, soil, and sunlight, the effects of a vehicle driving across permafrost tundra or of repeated and concentrated foot traffic may change permafrost laden tundra for decades or in some cases, permanently.

The effects of permafrost disturbance on poorly drained, ice-rich soils can be quite startling – mounds 10-50 feet (3-15 meters) in diameter, and up to 8 feet (2.4 meters) high, separated by trenches 1- 5 feet (.3-1.5 meters) wide, or pits 5-20 feet (1.5-6.1 meters) deep and 3-20 feet (.91-6.1 meters) across. On slopes, the thawing of permafrost can cause slope failures, mass earth movement, or landslides.

Tundra Puzzler 2

IS TUNDRA RADIOACTIVE?

Background Information

• The **radioactive isotope cesium-137** is a product of atomic fission reactions such as those in the explosion of nuclear weapons and in nuclear power plants. It has a **half-life** of 30 years, which means that it loses half of its radioactivity every 30 years. After 60 years, it still has 1/4 of its original radioactivity, and after 90, it has 1/8 its original radioactivity.

Cesium-137 has been released into the atmosphere by the testing of atomic weapons along the Pacific Rim and from the 1986 explosion at Russia's Chernobyl nuclear power plant. Much of the atmospheric testing occurred in the late l950s and early l960s.

• Cesium-137 has chemical properties that make it react with other chemicals in ways similar to the way potassium reacts with other chemicals.

• **Lichens** get the minerals they need mainly from rain and snowmelt.

• Potassium is an essential mineral for living things, including lichens. It occurs in the cells and fluids of living things. In mammals, the amount of potassium in the blood is regulated by the kidneys. Excess amounts are excreted.

• Rain and snow form around particles of dust in the air.

• The air in the earth's atmosphere circulates around the globe.

• The lifestyles of northern Alaska Natives have been changing. They have become more dependent on foods shipped in from elsewhere and rely less on subsistence hunting.

THE PUZZLE

Based on what you know about tundra ecology, the food chain, and the information given, **(a)** explain why higher concentrations of cesium-137 might be found in the tissues of humans and wolves who live in the arctic tundra than in the rain or soil of tundra. **(b)** Why do you think that the levels of cesium-137 in arctic people have declined in recent years?

Tundra Puzzler 2

IS TUNDRA RADIOACTIVE?

What Ecologists Have Learned

(a) Once released into the atmosphere, cesium-137 molecules are spread widely by air currents. These radioactive molecules settle back to earth, mainly in rain drops and snow flakes.

Because lichens get their minerals from rain and snowmelt water, and cesium-137 mimics potassium (a mineral they need), lichens rapidly take up and hold cesium-137 in their body tissues. Plants also take up and hold cesium-137, but at a slower rate than do lichens because they absorb water and minerals from the soil rather than directly from rain and snowmelt.

The soil itself traps and filters out some of the cesium-137, and some never reaches the soil as it flows away in run-off water. In addition, many plants die back and shed their leaves each winter. Most lichens, by contrast, hold the same tissues for years or even decades and thus may accumulate much of the cesium-137 they absorb.

During some winters, caribou eat mainly lichens. Their bodies respond to cesium-137 as they would react to potassium, by absorbing and holding it in their body tissues and fluids. The amount of cesium-137 held by a caribou depends on its diet and other factors.

When caribou feed mainly on contaminated lichens, they absorb and hold some of the cesium-137 that was originally taken up by the lichens. Humans and wolves who eat the caribou take up and hold the cesium-137 from the caribou tissue.

Humans and wolves who eat a lot of caribou that have fed upon heavily contaminated lichens can end up with surprisingly high levels of cesium-137 in their bodies.

In one study, scientists found concentrations of cesium-137 in lichens to be five times that found in rain and snow, and that in caribou four times greater than that in lichens. Humans and wolves had levels similar to or greater than those found in caribou.

It is important to note, however, that the retention of cesium-137 by lichens and other members of this food chain varies considerably. Cesium-137 is always transferred through lichen food chains, but concentration does not always occur.

The amount and rate of cesium-137 exchange through tundra food chains depend on many factors, including the amount of precipitation, the level of lichen contamination, the proportion of contaminated lichens in caribou diets (and what else is in their diet), plus the proportion of contaminated caribou and the kinds of other foods in the diet of the consumers of caribou.

(b) The level of cesium-137 in northern Alaska Natives has dropped because the amount of radioactive fallout has declined since atmospheric testing of nuclear weapons has become less common.

Also, Native people are eating more foods imported from elsewhere and fewer caribou, particularly in spring when concentrations of cesium-137 in caribou are highest (lichens are the main winter food of caribou).

Tundra Puzzler 3

HARD LIFE FOR ARCTIC BROWN BEARS

Background Information

The following information *approximates* the reproduction and **mortality** rates in a population of brown bears living in part of Alaska's arctic tundra. (*Actual mortality figures vary widely.*)

Female brown bears (grizzlies) in tundra areas do not begin producing young until they are eight years old, and then have one litter about every four years. Nearly all female bears have their last litter at about age 20, and die of old age after raising that litter.

In northern tundra areas, female bears give birth to two cubs per litter. On average, half of the cubs born are female.

Young bears have poor **survival rates**. About 40 percent of the cubs die before they are four years old.

For a bear population to remain stable or to grow, each female bear must produce at least one female young that survives to breed. This represents one female bear to replace her when she dies.

Bears four years and older usually have good survival rates. On average, only about 2 percent of these bears die each year from sources other than human-caused mortality. Most of these deaths are the result of accidents, disease, and fights among bears.

Because male bears fight more often than female bears, they have a higher death rate. Female bears five years and older outnumber adult male bears three to two.

The number of bears **harvested** by hunters is limited by regulations. Female bears with cubs cannot legally be killed unless in defense of life or property. Regulations allow people to harvest about 3 percent of the brown bears in a tundra population each year.

The combination of natural deaths and legal harvest of bears by humans means that about 20 percent of the adult females die every four years.

The number of bears killed in defense of life or property cannot be controlled by regulations. It can, however, be minimized by changes in human behavior. Brown bears are **omnivores** and are often attracted to garbage, dog food, birdseed, and campsites where food has been prepared. Changes in human behavior can lessen the frequency with which bears come in contact with people and their property.

In northern Alaska, 70 percent of the bears' natural diet is vegetation. They also feed on ground squirrels, marmots, bird eggs, and caribou and scavenge dead animals. They travel over **home ranges** from 60 to 700 square miles (155-1813 km^2) in search of adequate food supplies.

THE PUZZLE

Based on this background, **(a)** how many cubs could a single female brown bear living in an arctic tundra area produce in her lifetime, if she survived a full life span?
(b) How many of these would survive to age four?
(c) To breeding age (eight years)?
(d) What is the maximum number of female young that 100 female cubs could produce given the above mortality rates? *Calculate how many survive each four-year period of their lives to produce a litter of cubs, then multiply that number by the number of cubs produced. Divide by half to find out the number of females.*
(e) How many of these would survive to breeding age?
(f) Considering the given reproduction and mortality (death) rates, would the bear population remain stable, increase, or decrease?
(g) Imagine yourself as a bear biologist in the arctic with this information. Predict how increasing human populations and development may affect brown bear populations.

Tundra Puzzler 3

HARD LIFE FOR ARCTIC BROWN BEARS

What Ecologists Have Learned

Because of the slow reproductive rates of tundra brown bears, their populations grow slowly even under undisturbed circumstances.

In the example given, **(a)** one female will produce eight cubs in her lifetime, four of which will be females.
(b) Only 2.6 of the females will survive four years.
(c) Only two will survive to breeding age.

(d) If you calculate the survival of the 100 female cubs born, you will find that 40 survive to four years, **(e)** 32 to age eight (when they produce 32 female cubs); 27 to age 12, 22 to age 16, and 18 to age 20. By adding up the number of female cubs produced, (remembering that cubs are only produced every four years on average) you should find that 99 female cubs would be produced by each 100 female cubs born.
(f) This is just barely enough to keep the population stable.

(g) Because bears are wide-ranging and are attracted to human settlements, increasing human populations and development inevitably lead to more human-bear encounters. Because human-bear encounters often result in the bear being killed, the consequence of increasing human populations and development in tundra regions of Alaska is an increase in brown bear mortality.

A bear biologist who found the production and mortality rates given in the example would have to conclude that development could lead to a decline in brown bear populations.

BEAR OUTLOOK

Brown bears formerly ranged throughout the lower 48 states south to Mexico. Today, only two small populations remain in the lower 48 states – one in Yellowstone National Park and the other in the mountains around Glacier National Park.

Human development in bear habitat has been the main cause of brown bears disappearing from their formerly extensive range.

Today, harvest regulations help prevent humans from killing too many bears. As wild areas are developed, however, human-bear encounters increase and so does the number of bears killed by humans.

In tundra regions, where bear production is low and where individual bears must travel vast areas to find adequate food, scientists consider it very likely that increasing development will lead to bear population declines.

The information provided in the example is based on research by the Alaska Department of Fish and Game in northern Alaska. However, the actual reproduction and mortality rates of brown bear populations vary considerably from place to place and year to year. In other environments, reproduction rates are higher. Brown bear populations can withstand low levels of human harvest, but small increases in the number of bears killed can cause a population decline.

Tundra Puzzler 4

LICHENS, CARIBOU, AND ACID RAIN

Background Information

• **Lichens** are a symbiotic association of two kinds of living things. These include an **alga**, which **photosynthesizes** food, and a **fungus**, which provides a protective shell and helps absorb water and minerals from the environment. Lichens grow on soil, rocks, and wood.

• **Chlorophyll** molecules are found in leaves of plants and in **algae** cells. These molecules capture the sunlight energy used in photosynthesis.

• Lichens reproduce vegetatively. Vegetative reproduction does not occur on acidic surfaces or soils.

• Lichens obtain water and minerals primarily from rain and snowmelt water. They dry out in an absence of moisture, but soak up moisture like a sponge when it becomes available.

• Lichens live for many years and absorb air and waterborne particles much more quickly than do plants. This results in high concentrations of certain chemicals in their tissues.

• Lichens are an important winter food for caribou. The burning of fossil fuels (oil, gas, coal, and wood) releases a variety of chemicals into the air, including nitrogen dioxide, carbon dioxide, carbon monoxide, and sulfur dioxide.

• The atmosphere is made of several layers of air. The layers of air are constantly mixing and moving because of changes in air pressure, temperature, and moisture content. Large masses of air often travel thousands of miles over the earth's surface.

• Smoke from industries and power plants that burn fossil fuels often causes air pollution problems in nearby areas. These problems have been reduced by building very tall smoke stacks that send the smoke higher into the atmosphere where much of it is dispersed by winds and prevented from settling in nearby areas.

• When air pressure conditions are suitable, the water vapor in clouds condenses around particles and falls back to the earth as rain or snow. The precipitation carries the particles back to earth.

• The pH of soil, rocks, and wood is affected by the acidity of the precipitation.

• Many chemicals are soluble in water. That means they dissolve or become thoroughly mixed with water. The amount and kinds of chemicals dissolved in water determine the pH of the water. Concentrations of certain chemicals cause water to have a low pH – become **acidic.** These include sulfur dioxide and nitrogen dioxide. Other chemicals cause water to have a high pH – become **alkaline.**

• Sulfur dioxide and nitrogen dioxide – and compounds derived from these – change chlorophyll molecules so that they no longer function.

THE PUZZLE

Based on the given information and your knowledge of ecology, **(a)** explain how caribou populations of Alaska potentially could be affected by industrial development in Western Europe or Siberia. **(b)** What else might be affected?