Are We Having FUNGI Yet? Page 10

Quit Horsin' Around! Page 14

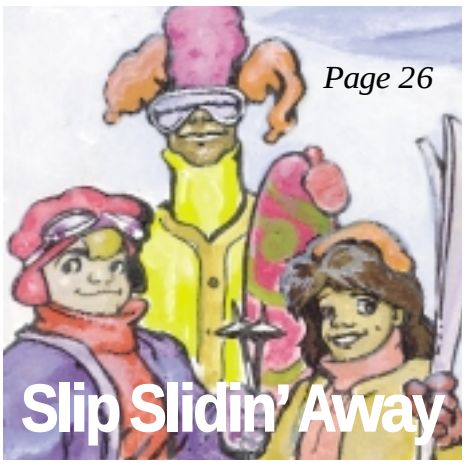
Go with the Flow Page 30

NATURAL INQUIRER

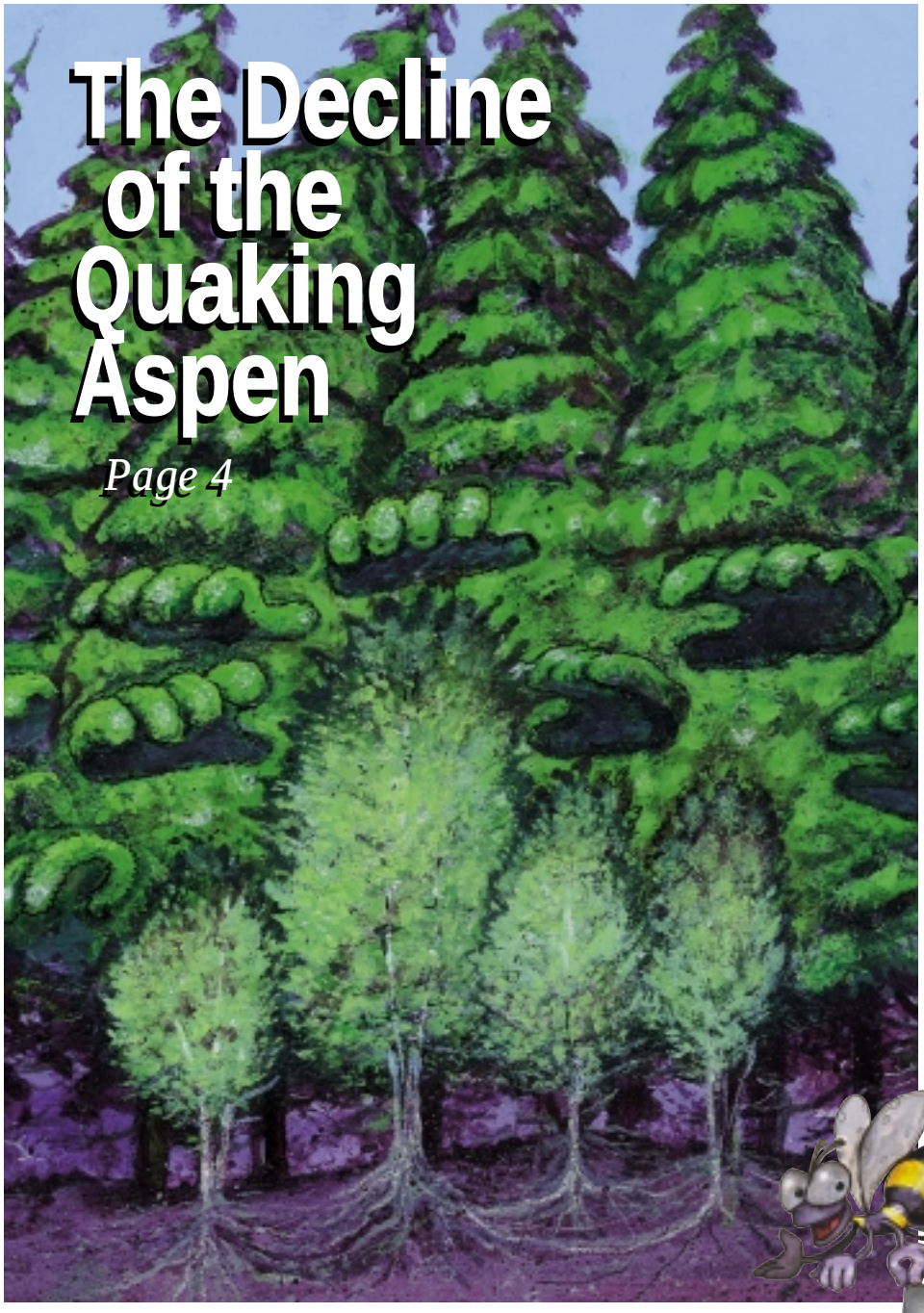
DECEMBER 1999 • USDA FOREST SERVICE

Finding Ways to Soak Up The Rays Page 18

Page 22 There Goes the Neighborhood!



Page 26 Slip Slidin' Away



The Decline of the Quaking Aspen Page 4

The Natural Inquirer
Volume 2, No. 1, Fall, 1999
The Rocky Mountain Ecoregion

Barbara McDonald
Forest Service Research

Forest Service Scientists:
Dale Bartos, Logan, UT
David Cole, Missoula, MT
Ken Cordell, Athens, GA
Debbie Dumroese, Moscow, ID
Christina Hargis, Flagstaff, AZ
Sandra Ryan, Laramie, WY
Anna Schoettle, Laramie, WY

Editorial Review Board:
Penny Stone's 6th Grade Class, Bennion Elementary School, Salt Lake City, UT
Caprielle Barlow
Robyn Brooks
Chris DelPorto
Ben Fogelson
Lisa Folau
Lillian Geurts
Daniel Hu
Raff Janove
Trent Lowe
Al Lund
Ian Nelson
Katherine Ogilvie
Bo Peng
Damon Peterson
Spencer Pinegar
Balery Pozo
Conor Provenzano
Brendan Schluter
Elisia Schrauth
Privank Sharma
Dallas Shi
Greg Thatcher
Mitch Towner
Ella White
Yan Yuan

Penny Stone (top right) and our Editorial Review Board

Produced by:
Forest Service Research, Washington, DC
Forest Service Conservation Education, Washington, DC

With Thanks To:
USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO
Forest Service 2002 Planning Team, Salt Lake City, UT
USDA Forest Service NatureWatch Program
Penny Stone, Bennion Elementary School, Salt Lake City, UT
Wilson Gonzalez-Espada, University of Georgia, Athens, GA
George Avalos, USDA Design Center, Washington, DC
Deron Davis, Dunwoody Nature Center, Dunwoody, GA
The College of Education, University of Georgia, Athens, GA

Page 4

Page 18

Page 26

Contents

Teacher's Note 2

About *The Natural Inquirer* 3

What are Scientists? 3

Features

Quaking in Their Roots:
The Decline of Quaking Aspen 4

Are We Having Fungi Yet?
Helping Young Trees Grow 10

Quit Yer Horsin' Around!
The Effects of Trampling
on Vegetation in Montana 14

Finding Ways to Soak Up the Rays
Lodgepole Pine Adaptation to
Different Environmental Conditions 18

There Goes the Neighborhood:
The Disruption of
American Marten Habitat 22

Slip Sliding Away: Who Goes Skiing
and Snowboarding in America? 26

Go With the Flow:
Are Mountain Stream Channels
Shaped by Flood and Drought? 30

Evaluation Forms 35

National Science Education Standards 37

What is the Forest Service? . . . . . .Back Cover

The *Natural Inquirer* is reproduced on recycled paper with soy-based inks.
Please pass this journal along or recycle it when you have finished using it!

Teacher's Note

Although students should learn about natural resources by reading these articles, one of the main purposes of the journal is to introduce the work of scientists to middle school science students. Our goal is to stimulate an interest in natural resource science by presenting research activities of a variety of scientists. First, you and your students will "*Meet the Scientist*."

In the articles themselves, "*Reflection Questions*" are oriented toward helping you conduct a class discussion about the problems, methods, findings, and implications associated with each research article. These questions should stimulate critical thinking about the article.

Critical thinking and discussion may be encouraged by using small groups, although entire class discussions may also be helpful. Note that the answers to the reflection questions should not be considered right or wrong. They are intended to stimulate critical thinking only.

The articles, as well as the journal's overall format, are designed to imitate the format of a professional research journal. We have, however, added a number of additional sections to serve as resources.

- First, the students will read the section called "*Thinking About Science*." This section highlights some aspect of the process of science that may be found in the article. The section called "*Thinking About the Environment*" highlights some aspect of the content of the article. A glossary is also included to help students understand the more challenging words in the article. The first occurrence of these words in the article is given in bold print. Understanding these words will be crucial to the students' comprehension of the article.

- Each article also contains a "*Discovery FACTivity*," which is a hands-on inquiry-based activity intended to illustrate some aspect of the article.

- In the back of the journal, you will find a matrix which will allow you to identify articles by the national standards that they address. National standards were identified from Project 2061, developed by the American Association for the Advancement of Science.

- Also in the back of the journal, you will find evaluation forms. After you have read an article with your class, please photocopy the forms, complete them, and send them to the address listed.

This journal was created by the Urban Tree House, an education program of the USDA Forest Service. If you have any questions or comments, please contact:

Dr. Barbara McDonald
Social Scientist
USDA Forest Service
320 Green Street
Athens, GA 30602-2044
706-559-4224
barmac@bigfoot.com

The Natural Inquirer

Scientists report their research in journals, which are special booklets that enable scientists to share information with one another. This journal, *The Natural Inquirer*, was created so that scientists can share their research with you and with other middle school students. Each article tells you about scientific research conducted by scientists in the USDA Forest Service. If you want to know more about the Forest Service, you can read about it on the back cover of this journal.

All of the research in this journal is concerned with nature, such as trees, forests, wildlife, insects, outdoor activities, and water. First, you will "meet the scientist" who conducted the research. Then, you will read something special about science, and then about the environment. You will also read about a specific research project, written in the way that scientists write when they publish their research in journals. You will become a scientist when you do the Discovery FACTivity associated with each article. Don't forget to learn the vocabulary words! They will help you to understand the article.

At the end of each section of the article, you will find a few questions to help you think about the research. These questions are not a test! They are intended to help you think more about the research. Your teacher may use these questions in a class discussion.

What Are Scientists?

Scientists are people who collect and evaluate information about a wide range of topics. To be a successful natural resource scientist, you must:

- **Be curious**
  You must be interested in learning.
- **Be enthusiastic**
  You must be interested in a particular topic.
- **Be careful**
  You must be accurate in everything you do.
- **Be open-minded**
  You must be willing to listen to new ideas.
- **Question everything**
  You must think about what you read.
- **Care about the environment**
  You must have an interest in and respect for the natural world.

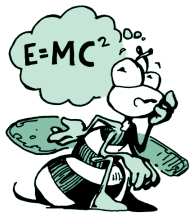
Scientists in this issue at work.

Quaking in Their Roots:

The Decline of Quaking Aspen

Meet Dr. Dale Bartos:

"I like being a scientist because I enjoy working with natural systems and attempting to understand how they function. I am able to communicate this information to the land managers who (it is hoped) will do a better job of caring for the land."



Thinking About Science...

Sometimes, a scientific question cannot be answered by direct observation, such as by an experiment or by simply observing what is going on. In these cases, scientists collect information from a variety of sources, then put the pieces together as if they were gathering and evaluating clues to a mystery. *In this study, the scientists wanted to know why populations of quaking aspens are declining in the Western United States.* Because it would take years to watch the growth and development of an aspen stand, the scientists tried to find clues from other sources to help them understand the aspen's decline.

Dr. Bartos counts tree rings with the help of a technician.

Thinking About the Environment...

Pando—which means "I spread" in Latin—is the perfect name for a stand of quaking aspen, nominated a few years ago as Earth's most massive living individual. The title still stands, as far as scientists have determined. In the Wasatch Mountains of Utah (on the Fishlake National Forest — see *Figure 1*), Pando

Glossary:

biodiversity: (bî'ô di vûr'si tê) various kinds of life

conifer: (kô'ne fer) cone-bearing evergreen tree or shrub

distribution: (dis' tre byôô'shen) the frequency of occurrence or places where a natural resource can be found

ecosystem: (ek'ô sis tem) a system formed by the interaction of organisms with their environment

forage: (fôr'ij) plant food eaten by wildlife, horses, or cattle

forest manager: (fôr'ist man'i jer) a person who takes specific actions to protect and to use natural resources in a forest

forest stand: (fôr'ist stand) a particular species of tree growing in a given area

natural history: (nach'er el his' te rê) history of changes in the natural environment over time

stability: (ste bil'i tê) being likely to continue

succession: (sek sesh'en) the natural replacement, over time, of one type of plant life after another

suppress: (se pres') to put an end to; to subdue or conquer

Figure 1. Aspen stand in the Fishlake National Forest, Utah.

weighs about 13 million pounds. He has upwards of 47,000 stems. That's 47,000 of what you and I might mistakenly perceive as separate aspen trees.

Pando is a male aspen. Unlike several other tree species, individual aspen are either male or female. Quaking aspens like Pando are able to cover so much ground by an asexual reproductive process—known as suckering—involving tree roots. New stems rise out of the ground from the aspen's network of horizontally spreading roots. On the surface, these appear to be separate trees, but they are really part of one individual! (This information is from *Earth and Sky*, Monday, December 9, 1996. Visit their web site at www.earthsky.com.)

Introduction

The quaking aspen is a tree that helps us a lot! Aspen use less water than *conifers*, provide *forage* for wildlife, and support a wide variety of other kinds of life. The quaking aspen thus helps to maintain the *biodiversity* of an area. Aspen are unique, because they reproduce by sending small shoots up from their root systems. This kind of reproduction is called suckering. In some ways, this is a disadvantage to them. If they are lost to an area, they will not reproduce from seeds like other trees.

In recent years, populations of quaking aspen have been in decline in the Western United States. Stands of aspen are now mixed with conifer trees. Each year, fewer aspen-dominated stands exist in Utah and other parts of the Western United States. To be classified as an aspen stand, the stand must be more than 50 percent aspen.

The scientists in this study wanted to know more about the decline of quaking aspen. They also wanted to know what should be done about reversing aspen decline, so that large aspen stands

are not lost in the Western United States.

Reflection

- If aspen declines, what environmental benefits will decline also?

Methods

The scientists collected information from a wide variety of sources. First, they researched the *natural history* of the area. They specifically looked at the history of fire and of the *distribution* of aspen. In part, they learned about the fire history from two ponderosa pine trees *(Figure 2)*. Even though ponderosa pine trees can't talk, they can still tell scientists about past fires. The scientists took a small slice from the trunk of each of the pine trees and examined the slice for fire scars near the trees' growth rings *(Figure 3)*.

The scientists also dug trenches in *forest stands* of pure aspen, and in stands with a mixture of aspen and conifer trees *(Figure 4)*. They pulled the aspen roots from these trenches and counted them. In this way, they could determine whether aspen reproduction was declining in stands being shared with conifers.

Figure 2. Ponderosa pine damaged by fire.

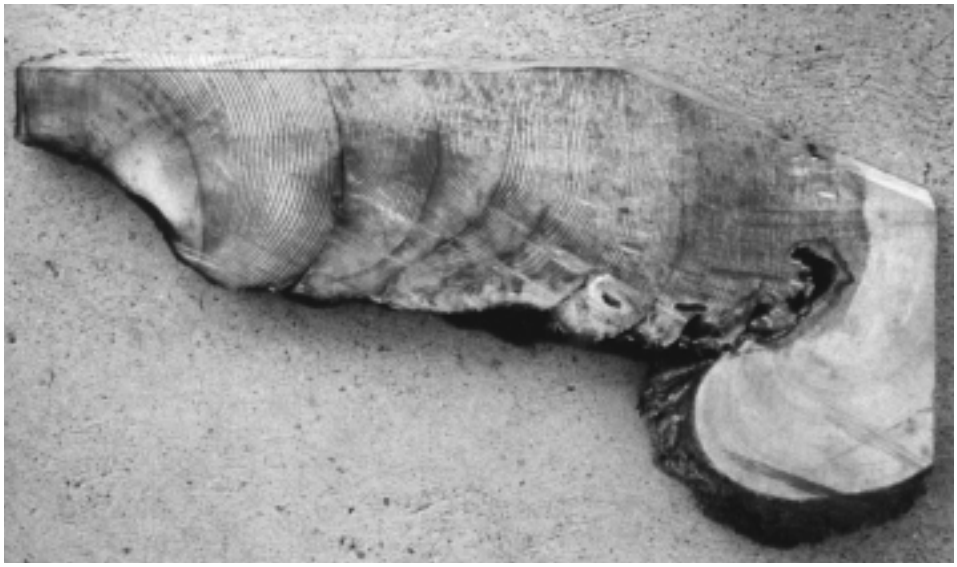


Figure 3. Fire-scarred growth rings from ponderosa pine.

Figure 4. Digging up the aspen roots and counting them.

Reflection

- What is it about the number of aspen roots that would tell the scientists that aspen reproduction is declining in mixed stands, as compared with stands with mostly aspen trees?

- What is the relationship between fire and the growth of conifer trees in aspen stands?

Results

By looking at the trunk slices, the scientists discovered that nine fires had occurred during the early lifetime of the Ponderosa pines, but that no fires had occurred since 1836. Prior to 1836, fires burned in this area about every 19 years. These fires were helpful to aspens because they reduced the competition of other species. Aspens regrew after the fires had burned, and, therefore, these small fires actually helped the aspen stands to remain healthy. Fire acted like a feedback mechanism that helped to keep the aspen *ecosystem* balanced within certain limits.

Over the past 150 years, humans have *suppressed* fires, and have allowed livestock to graze among the aspen. These activities have allowed forest *succession* to proceed. When this happens in aspen stands, the aspens begin to die and the areas become dominated by conifers and/or sagebrush. This is what is happening now to the aspen stands studied by Dr. Bartos and Mr. Campbell.

Reflection

- If fires are not allowed to burn, the aspen in an ecosystem are gradually replaced by other trees. How does fire maintain the stability of the aspen ecosystem?

Implications

Unless *forest managers* make some changes, the population of aspen trees in the Western United States will continue to decline. Recommended changes include reducing livestock grazing among aspen trees and beginning a program to allow fires to burn about every 20 years within aspen stands.

The scientists know a great deal about how to save the quaking aspen, but more research is needed. What they do know is that if the aspen population continues to decline, many of the environmental benefits of aspen ecosystems will also decline.

Reflection

- If you were the scientist, what would you suggest should be done about the decline of quaking aspen?

From: Bartos, Dale L. and Campbell, Jr., Robert B. (1998). Decline of Quaking Aspen in the Interior West— Examples from Utah, *Rangelands, 20(1)*: 17–24.

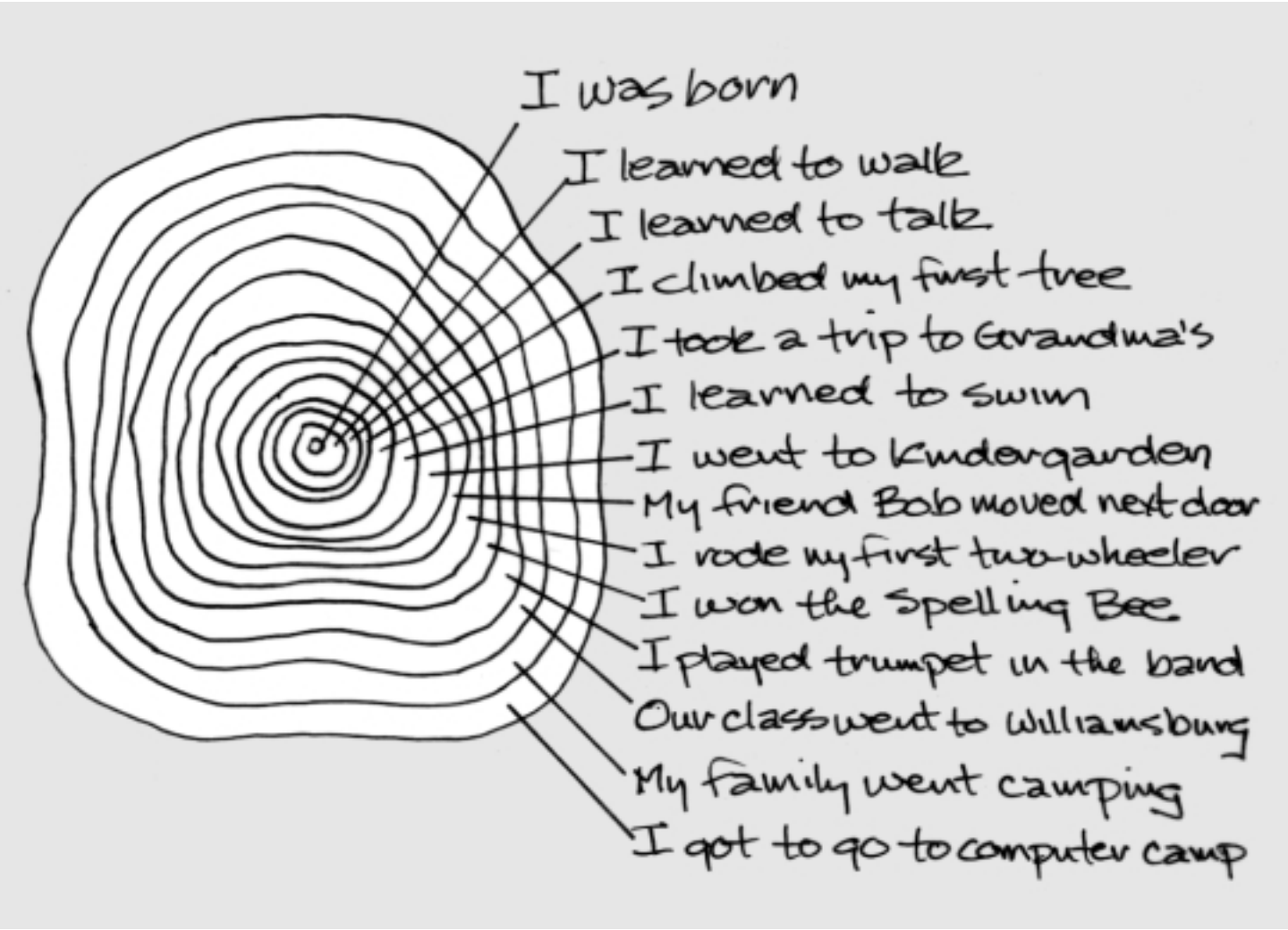
Discovery FACTivity

When a tree is cut down or a branch is cut off of a tree, the trunk or branch shows a pattern of rings. Each ring is a layer of wood produced during 1 year's growing season. Have your teacher bring thin slices from a cut tree or branch, enough for each student or for small teams of students. Carefully examine the rings. In years with good growing conditions, the area between rings is large, indicating a lot of growth. In years of drought, insect damage, fire, root damage, or other stress, the area between rings is small and may actually show the damage, indicating poor growth in that year. *See the example.*

What can you determine about the tree's (or branch's) life and the yearly environmental conditions by reading tree rings? See if you can even count the rings to determine the tree's (or branch's) age.

Just like trees, people grow each year. We are going to borrow the idea of reading tree rings, except that you are going to draw your own life story, just as if you were a tree. Get a plain piece of paper. Put a dot in the center. The dot represents the year you were born. Now, draw circles around the dot. Each circle represents a year of your life. If you grew a lot 1 year, leave a lot of area in between that circle and the next larger one. You can show memorable events in your life on the rings. Share your life stories with other students in the class. *See the example below*.

For more information, see: www.xmission.com/~rmrs/staffs/labs/logan/logan_int4301.html



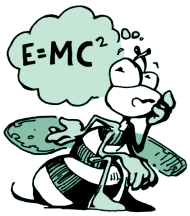
Are We Having FUNGI Yet?

Helping Young Trees to Grow

Meet Dr. Debbie Dumroese:

"I like being a scientist because I love learning about how different soils grow unique forest plants and fungi, and I like working on ways to continue harvesting timber without damaging the soil. The other reasons I like science are the opportunity to work with some especially gifted people, and to continue learning about the world."

Dr. Debbie Dumroese



Thinking About Science...

Scientists often use math to help them do their work. Can you guess why? When scientists do experiments or conduct research, they often measure the amount of something. Then, they compare the measurements to look for similarities or differences. Scientists also use numbers and words to present their results to other scientists. You can see that math and science are closely related. Can you guess what other subject is necessary to scientists? Think about *The Natural Inquirer*. Besides understanding numbers, what else do you need to do to learn about science? What are you doing right now?

Thinking About the Environment...

Scientists have discovered that certain fungi grow on the roots of plants, to the benefit of both the fungi and the plant. The fruiting bodies of fungi are mushrooms, but most of the organism lives underground. This *mutually beneficial* relationship between plants and fungi is called mycorrhiza (my koe rye' zuh). The fungi absorbs nutrients from the soil and provides them to the plant, and the plant provides *nutrients* to the fungi. Everybody wins! This is like many relationships in nature, where different kinds of

Figure 1. Ectomycorrhiza fungi growing on tree roots.

organisms work together so that they all remain healthy. This relationship works best when the organisms are all *native* to the area in which they are growing. The scientists in this study were interested in the fungi that grow on the outside of tree roots *(Figure 1)*. They call this ecto- (meaning outer) mycorrhiza fungi.

Introduction

In the Western United States, shallow, rocky soils and a dry climate often make it hard for new trees to grow on areas that have been harvested of older trees. Sometimes, areas that have been harvested grow back quickly in other types of plants. These plants compete with young trees for moisture and nutrients. This makes it hard for new trees to grow. Often before planting *seedlings*, foresters will clear an area of competing plants by setting fires and burning the plants. This does not always work well because the plants grow back quickly and again compete with the seedlings.

The scientists in this study wanted to test a different way of reducing the competition for soil nutrients and moisture. They did this by applying two different types of chemicals. One chemical was applied directly to the soil to kill the plants. The other chemical was applied directly to the seedlings, before the seedlings were planted. This was done to kill the non-native fungi that might be growing on the seedlings' roots. The scientists *hypothesized* that if the new seedlings were cleared of nonnative fungi before being planted, the native ectomycorrhiza fungi would spread from nearby forested areas and grow on the young seedlings' roots. This would help the seedlings to get nutrients, to grow faster and stronger.

Reflection

- What problem are the scientists trying to solve?
- If foresters do not plant seedlings on the harvested areas, what do you think will happen to the areas? Why do foresters want to plant seedlings in harvested areas?
- Why do you think native ectomycorrhiza fungi are better for the seedlings than nonnative fungi?

Methods

The scientists applied one kind of chemical to the soil before planting the seedlings. This procedure is called *fumigation* and involves pouring a liquid chemical onto the ground, then covering the ground with plastic *(Figures 2 and 3)*. The plastic keeps the chemical from escaping into the air. Why do you think that it is important to cover the ground with plas-

Glossary:

fumigation: (fyôo'me gâ'shen) a method used to kill weeds, insects, and disease organisms in soil, usually with a liquid or a gas

fungicide: (fun'ji sîd') a chemical used to destroy fungi

harvest: (här'vist) to gather or take a crop

hypothesize: (hî poth'i sîz') to propose an explanation in light of known facts

mutually beneficial: (myôô'chôô el'lê ben'e fish'el) each having and gaining advantage from the other or others

native: (nâ'tiv) living or growing naturally in a particular region

nursery: (nûr'se rê) a place where young trees or plants are grown

nutrient: (nôô'trê ent) something containing food

seedling: (sêd'ling) a young plant grown from a seed

timber: (tim'bêr) trees or their wood

Figure 2. Pouring liquid onto the ground.

Figure 3. Covering the ground with plastic.

tic? (Hint: Think about your health, and also about the loss of chemicals from the ground.) The plastic was removed from the ground 2 weeks before planting the seedlings.

The scientists also applied a fungicide directly to some of the seedlings in the *nursery* before planting them outside. The fungicide was applied to kill the fungi that grow on the seedlings' roots in the nursery. Some of these seedlings were planted in areas that had not been fumigated. That way, the scientists could find out whether fumigation affects the seedlings' growth. They could also find out if the application of a fungicide affects the seedlings' growth.

The scientists measured the growth of the seedlings every year for 2 years. They measured the seedlings' height, analyzed their nutrient content, and counted the number of seedling roots that had ectomycorrhiza fungi growing on them. (The scientists expected the native ectomycorrhiza fungi to begin growing on the roots, even though the roots had been exposed to fungicide.) In this way, they used numbers to compare the use of fungicide alone on seedling and ectomycorrhiza growth. They compared this with the use of fungicide and soil fumigation together on seedling and ectomycorrihiza growth.

Reflection

- Why did the scientists plant some seedlings in areas that had not been fumigated?

- Do you think the ectomycorrhiza fungi were able to begin growing on the seedlings' roots? Why or why not?

Results

The scientists found that when they fumigated the soil in the spring, the seedlings grew more than when they fumigated in the fall. They also discovered that the seedlings not treated with fungicide grew larger than those that had been treated with fungicide.

They found that the use of the fungicide resulted in a greater amount of ectomycorrhiza fungi growing on the seedlings' roots by the second year. When you think about all of these findings, you will see that the presence of more ectomycorrihiza fungi does not always mean that seedlings will grow larger, even though the fungi are providing nutrients to the seedlings.

Reflection

- If you want to grow the biggest seedlings, which treatment would you use? Would you use just the fumigation, just the fungicide, or both?

- Do you think the scientists were surprised to find that ectomycorrhiza fungi did not make the seedlings grow larger? Why or why not?

Implications

If foresters want their seedlings to grow successfully and quickly, they should fumigate the soil in the spring before they plant the seedlings. Unfortunately, soil fumigation is expensive. The scientists therefore recommend that fumigation only be used on areas where seedlings have a lot of competition from other plants.

Reflection

- What are some of the advantages and disadvantages of soil fumigation?

- This study pointed out examples of competition and cooperation in natural systems. Where was the competition? Where was the cooperation? What are other examples of competition and cooperation in nature?

- Even though the native ectomycorrhiza fungi did not help the seedlings grow larger, do you think the native ectomycorrhiza fungi are beneficial to the seedling? Why or why not?

From: Page-Dumroese, Alan E. Harvey, Martin F. Jurgensen, and Michael J. Larsen (1996). Ponderosa pine seedling response to planting-site soil fumigation and fungicide application, *Northwest Science, 70(2)*, 139–147.

Discovery FACTivity

Bring in a small bag of sterilized potting soil, and similar amounts of soil from the woods, a garden, and from an area with a lot of weeds or other types of plants. Think about the sterilized potting soil. What does sterilized mean? Why would people want to buy sterilized potting soil? Compare the sterilized potting soil with the other soil. Besides the color, what are the differences? Can you find any animal or plant life in the sterilized soil? How might that be an advantage or disadvantage to house plants?

Further Discovery

Plant a house plant using the sterilized potting soil, and one in each of the other soils. Treat them all the same. Over a period of months, observe what happens in each of the pots. Is there a difference between the pot with the sterilized soil and the other pots? What is the difference? Why is there a difference?

For more information, see: http://forest.moscowfsl.wsu.edu/

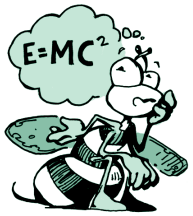
Quit Yer Horsin' Around!

The Effects of Trampling on Vegetation in Montana

Meet Dr. David Cole:

"I like being a scientist because I get to exercise my curiosity and discover things that might help make the world a better place."

Dr. David Cole



Thinking About Science...

Scientists often set up experimental conditions to study a particular problem. If scientists control what happens during an experiment, they feel more certain about the results. Often, scientists will compare what happens under different conditions. When they work in a laboratory, it is easier to control conditions. Sometimes, however, scientists cannot do their experiments in a laboratory. The scientists in this study wanted to find out whether horses or llamas do more damage to Rocky Mountain vegetation. Do you think they did this study in a laboratory?

Thinking About the Environment...

Whenever people use *natural resources*, they have an impact on them. The scientists in this study were concerned about the impact of large *domestic* pack animals used to carry equipment in the *back country*. Large animals may have more of an impact on vegetation than smaller animals and humans. This is of special concern in mountain environments, which are more *fragile* for vegetation. The scientists studied the difference in impacts between horses and llamas. Llamas are a South American member of the camel family. Llamas are about 4 feet high and 4 feet long (plus a short tail!). They were used as pack animals at least 4,000 years ago by the Indians of Peru.

Introduction

When people go hiking or camping in back country or wilderness areas, they almost always impact the natural environment in some way. For example, hiking along trails wears down the soil and caus-

es *erosion*. A look at the trails around your school yard or in your local park will show you what happens when there is a lot of trail use. When people use the back country, they sometimes use pack animals to make their trip easier. In the past, people used horses, mules, and donkeys to carry their load. More recently, people have also begun using llamas to help them carry their hiking and camping gear.

While much *trampling* occurs on trails, for pack animals, it can also occur where the animals are grazing. Scientists know very little about the environmental impacts of pack animals on vegetation. *But since so many people are using horses and llamas when they visit the back country, it is important to understand what happens to vegetation that is being used by these people and their animals.* That's why Dr. Cole and Dr. Spildie studied what happens to vegetation that is being trampled by people, horses, and llamas.

Reflection

- What problem are the scientists trying to solve?
- If you were the scientist, how would you find out about the effects of trampling by horses, llamas, and people?

Method

The scientists found places to study in the back country. To study the effects of trampling on the *vegetation*, four sets of lanes were created. A lane was created by marking a long and skinny area, like a path. The lanes went right through the vegetation (like the first time anybody uses a short cut!). One set of lanes was used as a *control*. The control, which was left untrampled, was used to compare what happened in the trampled lanes with an untrampled lane.

That left three sets of lanes for the *treatments*. One of the 3 sets of lanes was trampled by a human walking down the lane 150 times, another was trampled by a llama —being led by a human— walking down the lane 150 times, and the third was trampled by a horse—being led by a human—walking down the third lane 150 times *(Figures 1 and 2)*.

The scientists measured the forbs (or small herb-like plants) and shrubs before and within 2 weeks after trampling in each of the lanes. They measured *vegetative cover* and height. Then, they calculated the average amount of cover and the average height of the forbs and shrubs in each of the lanes. The scientists then used a *statistical test* to determine whether the measured differences in vegetative cover and height were probably due to something other than normal vegetative differences.

Glossary:

back country: (bak kun'trê) a large natural area with little or no human development

control: (ken trôl) situation in which the experimental treatment is withheld, used as a comparison

domestic: (de mes'tik) raised to live in a tame condition

erosion: (i rô'zhen) the state of being destroyed by wearing away

experimental condition: (ik sper'e men'tel ken dish' en) a situation purposely created to run a test or trial

forest manager: (for'ist man'i jer) a person who takes specific actions to protect and to use natural resources in a forest

fragile: (fraj'el) easily damaged

natural resource: (nach'er el rê'sôrs) goods occurring in nature that are used by humans

statistical test: (ste tis'ti kel test) a test that uses numbers and probability to determine relationship

trampling: (tramp'ling) treading or stepping heavily

treatment: (trêt'ment) a purposeful action taken to test something or run a trial

vegetation: (vej'i tâ'shen) all the plants or plant life in a place

vegetative cover: (vej'i tâ'tiv kuv'er) layer of green vegetation

Figure 1. Leading the llama down the test path.

Figure 2. Leading the horse down the test path

Reflection

- What were the scientists trying to measure?
- Why do you think the scientists used a control?
- What do you think the scientists discovered about the effects of trampling on vegetation? Why?

Results

The amount of vegetative cover was so much lower for the lanes trampled by the horse, the scientists knew it had to be due to the horse *(Figure 3)*. However, the scientists found no statistical difference in the height of the vegetation. This means that even though the average heights were different for the vegetation in each of the treatments, they were not different enough to know for sure whether the horse or llama caused any more damage to the height of the plants than the human.

In general, the horse caused a lot more damage to the vegetation than either the llama or the human. The scientists were surprised to find that llamas did not cause more damage to the vegetation than humans. Are you surprised?

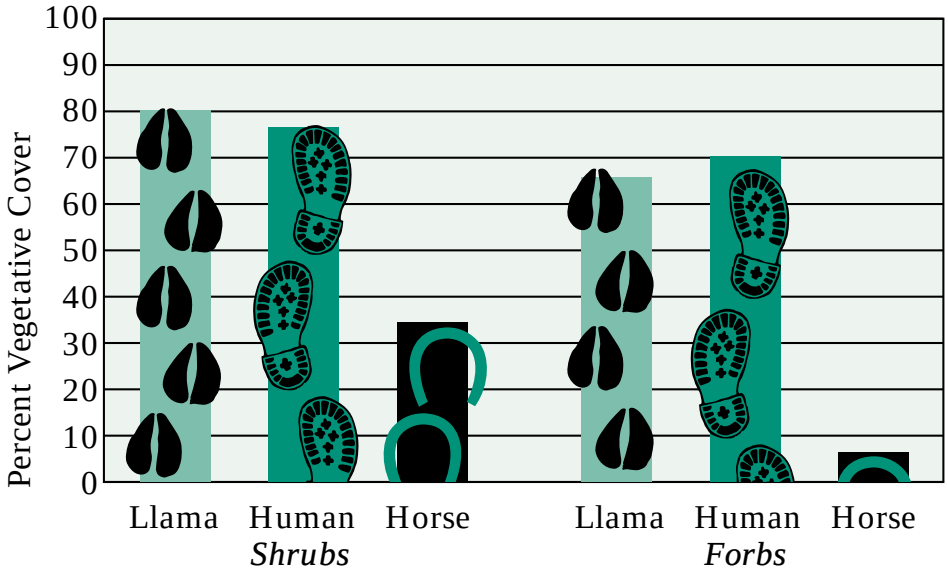


Figure 3. Bar chart of the results of the experiment.

Reflection

- Do you think the results are accurate? Do you believe that llamas do not create any more damage to vegetation than humans? Why or why not?
- If you were a forest manager, what would you do to protect vegetation from too much damage?

Implications

If forest managers want to minimize the impact of visitors to the back country environment, they need to be aware that horses are more damaging to vegetation than llamas or people. Managers may want to limit the use of horses for packing gear, and encourage the use of llamas instead.

Reflection

- When people use the back country for hiking and camping, even if they don't use horses, they have an impact on the environment. Do you think

people should be allowed to go in to the back country? Why or why not?

From: Cole, D. N. and Spildie, D. R. (1998). Hiker, horse and llama trampling effects on native vegetation in Montana, USA. *Journal of Environmental Management, 53*, 61–71.

Discovery FACTivity

The scientists in this study wanted to know whether trampling has an impact on plants. We're going to try the same experiment, but instead of using horses and llamas, we'll use aluminum cans and a plastic bottle. And instead of trampling, we'll be pounding!

Line four shoe boxes with plastic. Dig up four small rectangles of weeds, small enough to fit in the shoe boxes. Make sure to dig up some of the soil as well. The four weed samples should be as similar as possible, so dig them from the same area. Place one sample in each shoe box. Number each of the boxes. Using a ruler, measure the height of the weeds at each corner and in four places in the middle.

Calculate the average height of the weeds in each shoe box. Make a record of the average height of each sample.

Compare the average heights of the weeds in all four boxes. They should be very similar. If they are not, you will need to dig samples again until you get four samples with very similar average heights.

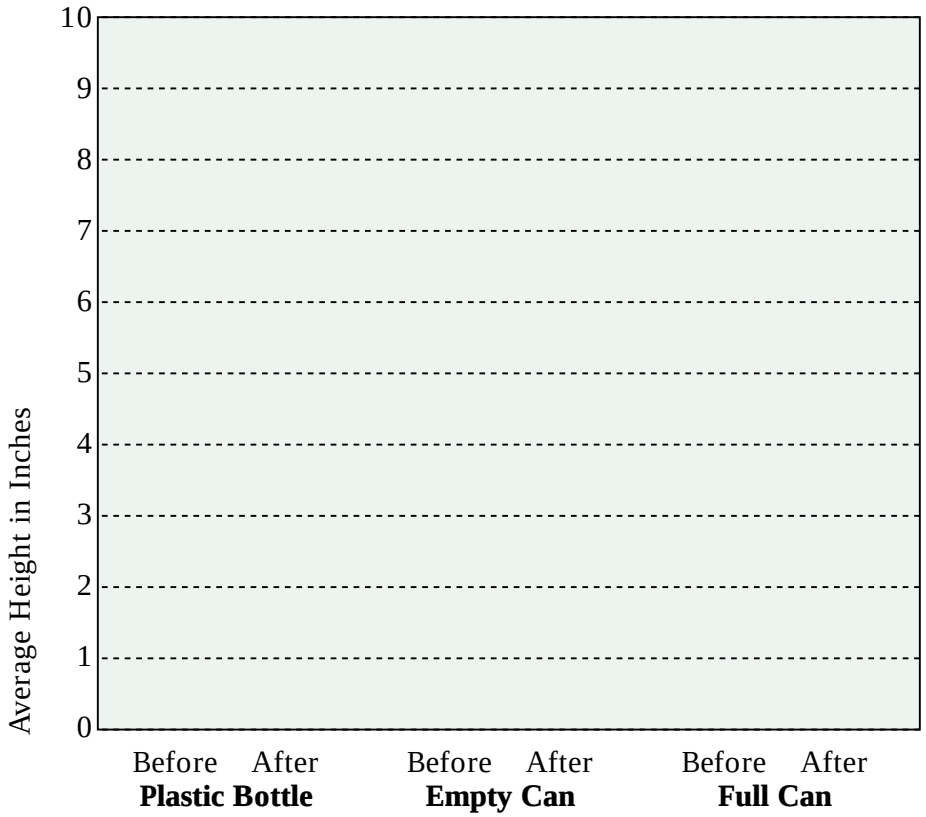
Get a plastic bottle filled with water, and two empty aluminum cans. Fill one can with sand or small rocks and tape the hole shut. Leave the other can empty.

Box number 1 will be your control. You will use it for comparison, so you will not do anything to the weeds in it. Have your class form three teams, choosing three members from each team to pound the weeds. Assign one of the remaining boxes and the plastic bottle or one of the aluminum cans to each team. Have the 3 members of each team pound the weeds 50 times (for a total of 150 times) with the bottle or can. Make sure all areas of the box are pounded.

After the weeds have been pounded 150 times, measure their height once again. Measure in each corner, and in four places in the middle. Calculate an average of the height of the weeds in each box, and record it. Compare the average heights of the weeds in all four boxes. Which box contains the lowest weeds? Which contains the highest? Why do you think there are differences between the heights of the weeds? What is the purpose of the control box?

Using the average heights you calculated for each box, create a bar chart showing your results using the empty chart below.

For more information, see: http://absaroka.wilderness.umt.edu/leopold

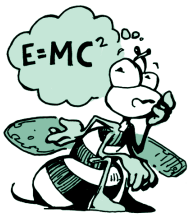


Finding Ways to Soak Up the Rays

Lodgepole Pine Adaptation to Different Environmental Conditions

Meet Dr. Anna Schoettle (pronounced "shuttle"):

"I like being a scientist because it is fun to ask questions, solve problems, and discover new information about plants and ecosystems."



Thinking About Science...

Scientists work in a variety of settings, and are employed by different organizations. Scientists work for universities, business and industry, hospitals, and the government. Scientists work in many different settings, such as laboratories, classrooms, factories, oceans, forests, in space, or on farms. The scientist in this study works for the USDA Forest Service, a Government agency that manages many of our Nation's forests. She collected branches from pine trees in the Rocky Mountain forests of Colorado. Then, she took the branches into a laboratory, took measurements of the branches and pine needles, and used a computer to compare her results. You can see that scientists work in a lot of different settings. What setting would you like to work in?

Dr. Anna Schoettle

Thinking About the Environment...

Organisms must be able to live in a constantly changing environment. (Think about yourself. Don't you need to do that too?) If an organism is to survive, it will try to keep its internal environment stable, regardless of the external environment. This means that organisms will try to ***adapt*** over time to survive in changing environments. The scientist in this study wanted to know why lodgepole pines can survive at very different ***elevations*** in the Colorado Rocky Mountains. This shows that the pines can live in very different environ-

ments. The scientist was interested in discovering how lodgepole pines adapt to living in such different environments.

Introduction

Sunlight is the source of energy for plants, which create food through *photosynthesis*. Photosynthesis occurs in the *foliage*, or green leaves (or needles) of a plant. The amount of food a plant can produce is partly dependent on the amount of its leaf or needle surface area.

Lodgepole pines grow in mountain forests at very different elevations. Dr. Schoettle, the scientist in this study, *hypothesized* that pines growing at higher elevations adapt to these harsher environmental conditions by growing needles that live for more years than needles growing at lower elevations. She also hypothesized that the shoots (branches) of higher-elevation pines would grow less each year than the shoots of pines growing in the lower elevations. *The interaction of growing less and the longer lifespan of the needles should equal out across elevations, maintaining the same amount of green needle area available for photosynthesis by the pines. Dr. Schoettle hypothesized that lodgepole pines have adapted in this way to live at different elevations.* She wanted to test this hypothesis.

Reflection

- Why might it be important for plants to be able to adjust to different environments? (Hint—Can a plant move from place to place?)

- How does one test a hypothesis?

Methods

When scientists study things, they usually study more than one example of it. The scientist therefore selected six forested areas at two elevations (three sites at each elevation). Four trees in each of the six areas were selected for study. (How many trees did the scientist study?) Then, the scientist selected an area in the lower third of each of the trees' *crown* from which she cut shoots. Dr. Schoettle measured four things: 1) the length of the shoot that had attached needles, 2) the age of the oldest pine needle on the shoot, 3) how much the shoot had grown each year, and 4) the total *biomass* of the needles on the shoot *(Figure 1)*. Biomass is measured by weight. The weight of the needles was measured by drying them in an oven and weighing them.

Dr. Schoettle then compared the four measurements using a computer program. The computer program helped her to determine if there were differences between the measurements of the shoots on trees growing at different elevations.

Glossary:

adapt: (edapt') to adjust to new conditions

biomass: (bî'o mas) that part of a habitat consisting of living matter

crown: (kroun') the leaves and living branches of a tree

data: (dât'e) information

elevation: (el'e vâ'tion) the height above sea level

foliage: (fôl'ê ij) leaves of a plant or all plants

hypothesize: (hî poth'e sîz) to propose an explanation in light of known facts

photosynthesis: (fôtô sin'the sis) the process that plants use, with the aid of sunlight, to create food in the form of carbohydrates

Characteristic	Site Elevation 2,800 meters	3,200 meters
Average shoot length in centimeters (cm)	19.9	20.7
Average needle lifespan (years)	9.5	13.1
Average annual shoot growth $(cm)^2$	2.1	1.4
Average needle biomass per shoot (grams)	4.6	5.9

Table 1. Effect of elevation on shoot characteristics of lodgepole pine.

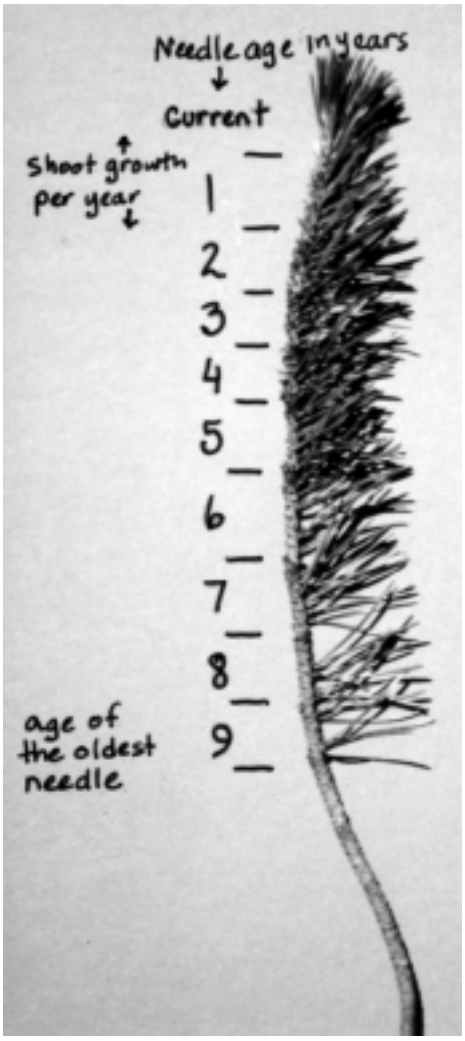


Figure 1. Measurements taken on each pine shoot.

Reflection

- Why do you think scientists usually study more than one example of something? Do you think Dr. Schoettle should have studied only one tree at each elevation, rather than 12? Why or why not?

- Why did Dr. Schoettle want to know the total weight of the needles? (Hint—Weight is a measure of the amount of something, and Dr. Schoettle wanted to know the amount of green needle area available for photosynthesis.)

Results

The results of the study are presented in Table 1. The needles growing on pines at higher elevations lived longer than the needles growing on pines at lower elevations. The shoots of these higher elevation pines, however, did not grow as much each year as the branches at lower elevations. The length and weight of the needles on all shoots were about the same, meaning that the same amount of green area was available for photosynthesis, regardless of where the trees grew.

Reflection

- What conclusion would you draw from these results about the adaptation of lodgepole pine at higher elevations?

- Was Dr. Schoettle's hypothesis proved true or false by this study? How do you know whether it was true or false?

- What conditions do you think are different between locations at high and low elevations? How might temperature be different? Why should this affect how plants grow?

- How many years do leaves live on trees near your school?

Implications

The scientist concluded that the lifespan of needles in lodgepole pine can vary, and may interact with the yearly growth of the shoot to produce the same amount of green area regardless of elevation. This may represent an adaptation of lodgepole pine, enabling it to live in a wide variety of environments.

Reflection

- Can you think of other examples of adaptations in nature?

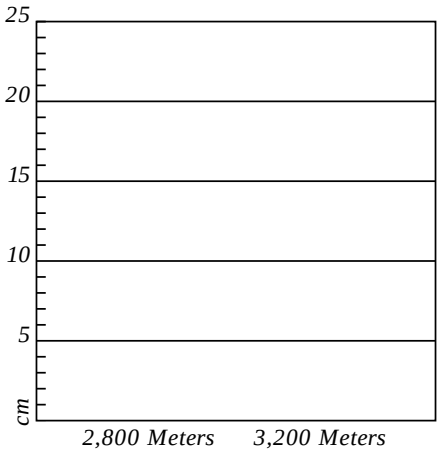
From: Schoettle, Anna W. (1990). The interaction between leaf longevity and shoot growth and foliar biomass per shoot in Pinus contorta at two elevations. *Tree Physiology, 7*, 209–214.

Discovery FACTivity

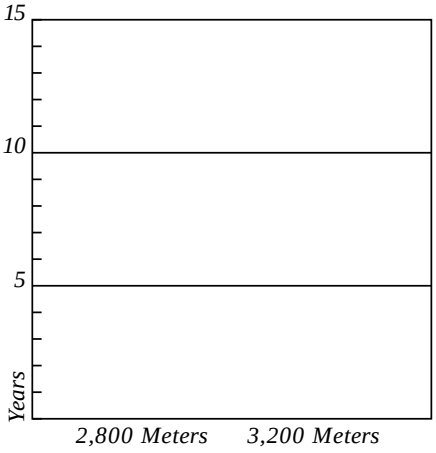
Bring in a cactus, a fern, and a plant that is native to your local environment. The cactus has adapted to a hot, dry, sunny environment. The fern has adapted to a shady, warm, wet environment. What kind of environment does your local plant live in? Carefully observe each of the plants. Compare them. How thick are each of the stems? Do the stems look different from one another? How are the leaves similar or different? Do the plants feel different to the touch? (Be careful with the cactus!) With the help of your teacher, explore how each plant has adapted to its native environment.

Another FACTivity!

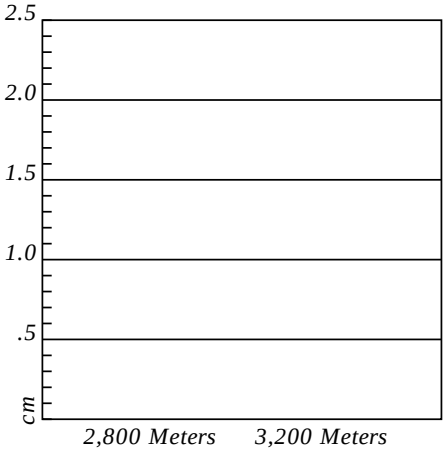
Using their numeric results, scientists often present their findings as charts or graphs. Using the data from Table 1, you will create your own bar charts. With the help of your teacher, complete the bar charts below. Turn to page 16 to see an example of a bar chart.



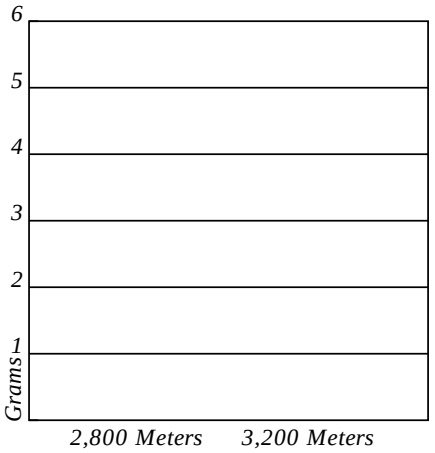
Average Shoot Length in Centimeters (cm)



Average Needle Lifespan (Years)



Average Annual Shoot Growth (cm)²



Average Needle Biomass Per Shoot (Grams)

The charts you have created present the same data as Table 1. Which kind of presentation do you prefer? Why? What are the advantages of using charts instead of tables to present data? What are the disadvantages?

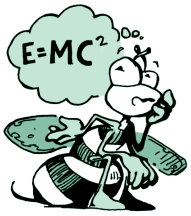
For more information, see: www.xmission.com/~rmrs/staffs/labs/laramie/lar_rm4352.html

There Goes the Neighborhood:

The Disruption of American Marten Habitat

Meet Dr. Christina Hargis:

"I like being a scientist because I get to find out new things about the world that nobody else has discovered. Usually the things I discover are very small facts, but often they turn out to be important pieces of information. I hope that the discoveries I have made about martens and other animals will help us do a better job of keeping wildlife from going extinct."



Thinking About Science...

Scientists often study animals in their natural *habitat*. When they do this, they try not to disturb or harm the animals. Sometimes, they can study animals from far away using photography or other forms of observation. Often, however, they need to take measurements of individual animals to understand whether they are healthy or sick, and sometimes just to identify them. Scientists use *live-traps* to capture animals without harming them. Then, they can examine the animal up close before returning him or her unharmed to the environment. Scientists have *ethical* standards so that they do not harm the individuals they want to study. The scientists in this study wanted to learn about a weasel-like animal called the marten. They used live-traps to study the martens before returning them to their environment.

Dr. Christina Hargis holding a baby marten.

Thinking About the Environment...

The American marten is a carnivorous mammal that lives in forests throughout Alaska, Canada, and the Northern United States. Martens are related to minks, and just like minks, they have slinky bodies and soft, rich fur. They eat mostly mice and squirrels, but sometimes they eat berries and *carrion*. They hunt for small animals by slipping quietly around big logs and tree trunks in forests. Martens avoid places that do not have trees because it is difficult for them to hunt in open areas.

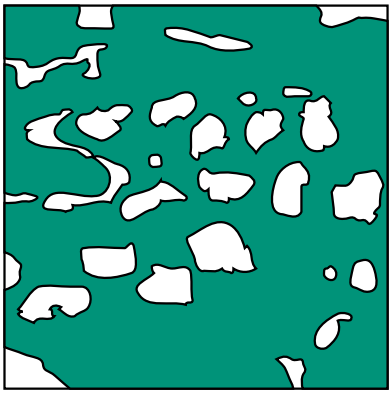
Introduction

In many places where martens live, trees are *harvested* for wood products, leaving martens with an environment very different from the *forested* one they prefer. When tree harvesting occurs, the marten's habitat is broken up, large patches of open land are created, and the forest environment remains only in little patches, or fragments. *What happens to martens if they keep finding more open areas every time they go hunting for food? Dr. Hargis and Dr. John Bissonette, the scientists in this study, wanted to know if marten populations are shrinking because of forest fragmentation.*

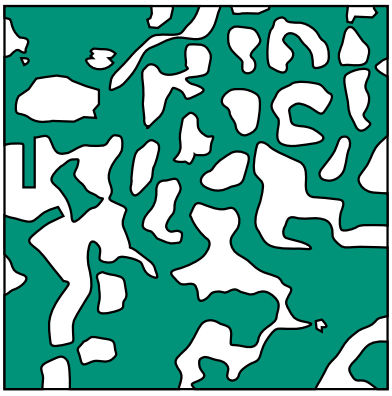
Reflection

- Why is it important to know whether marten populations are shrinking?
- How do you think the scientists found out about the marten population?

2% Unforested



21% Unforested



42% Unforested

Figure 1. Different levels of forest fragmentation.

Glossary:

associated: (e sô'shê â'ted) closely related or connected

carnivorous: (kär niv'er es) characterized by feeding on animals

carrion: (kar'ê en) dead and putrefying flesh

ethical: (eth'i kel) relating to what is good and bad; moral obligation

extinct: (ik stingkt') no longer existing

forest manager: (for'ist man'i jer) a person who takes specific actions to protect and to use natural resources in a forest

forested: (fôr'is ted) an area characterized by dense growth of trees and underbrush

fragmentation: (frag'men tâ'shen) to break apart and detach

habitat: (hab'i tat') the place where a plant or animal naturally lives and grows

harvest: (här'vist) to gather or take a crop

live-trap: (lîv trap) a trap that captures an animal alive and unharmed

population: (pop'ye lâ'shen) the total of individuals occupying an area

population density: (pop'ye lâ'shen den'si tê) the compactness or crowdedness of a population

scarce: (skârs) not plentiful or abundant

Methods

The scientists selected 18 separate sites—each about 3.5 square miles (9 km^2) in size—in the Uinta Mountains of northern Utah so that many levels of forest fragmentation could be studied. The sites ranged from 2 percent to 42 percent unforested land *(Figure 1)*. Some of the sites were almost completely forested, while others were only about half forested. These sites were like a patchwork of open and forested land.

The scientists set 25 live-traps in each of the 18 areas and checked them for 6 nights in a row. If a marten was captured in a trap, he or she was tagged, examined, and released back into the environment. The scientists recorded each marten's weight, sex, estimated age, and whether the marten was a reproducing female. The scientists counted the number of individual martens captured in the 25 live-traps placed in each of the 18 areas over the 6 days. (How many total opportunities to capture martens did they create?) The number of martens identified in each area was used as a measure of the population density of martens within that area. Then, the scientists compared the *population density* of martens in each area to determine whether higher levels of forest fragmentation were *associated* with lower marten population density.

The scientists also used live-traps to capture, count, and estimate the number of smaller mammals on each site. They did this to understand whether the martens' food supply on each site was plentiful or *scarce*.

Reflection

- Why do you think the scientists tagged the martens?
- Why do you think the scientists recorded the martens' weight, sex, age, and reproductive status?
- Think about the reasons the marten population might decline, remain stable, or increase. Why did the scientists want to know if the martens' food supply was plentiful or scarce?

Findings

The scientists found that on the more fragmented forest sites, fewer martens were captured. In fact, the scientists only captured one marten on any site that was more than 25 percent unforested *(Figure 2)*. The scientists also found that the martens' food supply was plentiful. Dr. Hargis and Dr. Bissonette concluded that forest fragmentation has a negative effect on marten population density, even when the martens' food supply is abundant.

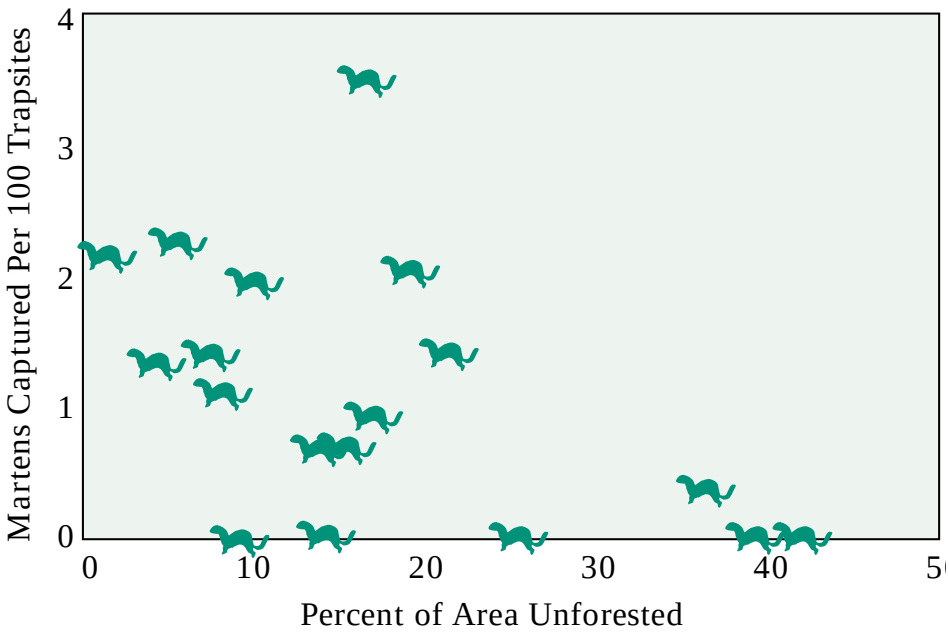


Figure 2. Each point (marten) on the graph represents one of the 18 sites studied. The scientists only captured one marten on any site that was more than 25 percent deforested. No martens were captured at five of the sites.

Reflection

- If the martens' food supply had not been plentiful, what conclusion could the scientists make about forest fragmentation and the decline of the marten populations?

- If you were the scientists, what would you tell forest managers they can do to help stop the decline of marten populations?

Implications

If forest managers want martens to live in the forests they manage, they must be careful to harvest trees so that no more than 25 percent of each 30-acre site, or about 7.5 acres, is harvested. It is also important not to cut trees in a patchwork pattern, but to leave large areas forested so that martens can live in the forest.

Reflection

- What human activity is impacting the marten population?

- What might happen to the marten population if *forest managers* do not heed the advice of these scientists?

- What might happen to the populations of rodents, rabbits, birds, fruit, and insects if the marten population gets very small?

- Is it important to stop the decline of the marten population? Why or why not?

From: Hargis, Christina D. and Bissonette, John (1997). Effects of forest fragmentation on populations of American Marten in the intermountain west, In G. Proulx, H. N. Bryand, and P. M. Woodard (Eds.). *Martens: taxonomy, ecology, techniques, and management,* Provincial Museum of Alberta, Edmonton, pp. 437–431.

Discovery FACTivity

The scientists in this study wanted to know about the forest habitat of the American marten. In this FACTivity, we are going to study different soil habitats. Get five shoe boxes and line them with plastic. Fill the shoe boxes with soil from five different areas. These areas can be:

1) a forest,
2) a compost pile,
3) a roadside,
4) a lawn, and
5) a garden.

Make sure that you have supervision when you are digging up soil from the roadside. And, be sure to get permission to dig the lawn soil. Carefully investigate the different soil samples. Do not injure any animals as you study them, and disturb them as little as possible. What kind of animals are living in each of the soil samples? How many animals are living in each of the soil samples? What do you think caused the numbers and types of animals to be different in each sample? Which soil sample has been altered the most by humans? Which one has been altered the least by humans? Are some human activities helpful to animals? Which ones?

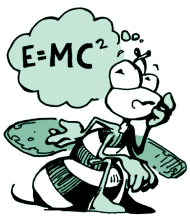
Be sure to return the animals and the soil to their original environment!

Slip Sliding Away

Who Goes Skiing and Snowboarding in America?

Meet Dr. Ken Cordell:

"I like being a scientist because my job is interesting and because people use the results of my work in planning for the future. As an added bonus, the pay is good which rewards me for the years I put into college studies."



Thinking About Science...

Scientists can study all kinds of topics and still be interested in the natural environment. This study focused on people and is a type of science called social science. Social science is concerned with the feelings and behavior of people. To find out about people's behavior, social scientists can observe them or ask them questions. In this study, the scientist asked a lot of people a series of questions about what they do out of doors in their free time.

Dr. Ken Cordell

Thinking About the Environment...

What do you need to have to go downhill skiing? Well, of course—you need mountains and you need snow! Not every place has these two *natural resources*. Places that have mountains and snow attract visitors who spend a lot of money doing things like skiing. This can help the local *economy* of an area by providing jobs that support activities like skiing. Skiing and other outdoor activities depend upon a healthy and beautiful environment. It is important to realize that the environment can help the economy, but that it must also be cared for. If we take care of our environment, it can continue to provide resources for human use and enjoyment into the future.

Introduction

Do you know anyone who has gone snow skiing or snowboarding in the past year? Chances are that you do. It might even be you! Over the past 30 years, outdoor activities like skiing have been growing in popularity, with more and more people going outdoors to have fun. Public agencies, like the USDA Forest Service, and private companies, such as ski resorts, need to know how many people do activities like skiing, and how many more might like to do these activities in the future. If they estimate that more people will go skiing, for example, they can be better prepared to provide the things people need to go skiing. Every 10 years, the USDA Forest Service studies lots of *outdoor recreation* activities, and reports whether the number of people doing each of those activities is rising or falling. Dr. Cordell, the scientist in this study, wanted to know how many people across the United States went downhill skiing and snowboarding in the previous year.

Reflection

- What do people need to have to go downhill skiing? (Hint—They need more than equipment, like skis and warm jackets. They also need snow, a warm ski lodge, and someone to operate the ski lift.)

- What might happen if agencies and companies did not know how many people might want to go skiing?

- If you were the scientist, how would you find out how many people went skiing or snowboarding last year?

Methods

Dr. Cordell used a *questionnaire* to find out how many people went skiing and snowboarding in the last year. Because he could not ask everyone in the United States his questions, he had to use a sample of people across the country. So that his sample

Glossary:

average: (av'er ij) the arithmetic mean; about midway between all of the values

bias: (bî'es) a personal judgment that might introduce error into a research project

demographic: (dê'me graf'ik) portraying the general characteristics of a population of people

economy: (i kon'e mê) a system relating to the production, distribution, and consumption of goods and services

estimate: (es'te mât') to determine approximately the size or extent of something

income: (in'kum) the amount of money a person makes

natural resource: (nach'er el rê'sôrs) goods occurring in nature that are used by humans

outdoor recreation: (out'dôr rek'rê â'shen) activities done out of doors for fun

questionnaire: (kwes'che nâr) a set of questions used to obtain information from people

sample: (sam'pêl) a representative part of a larger whole

trend: (trend) a numeric representation of a change in quantity over time

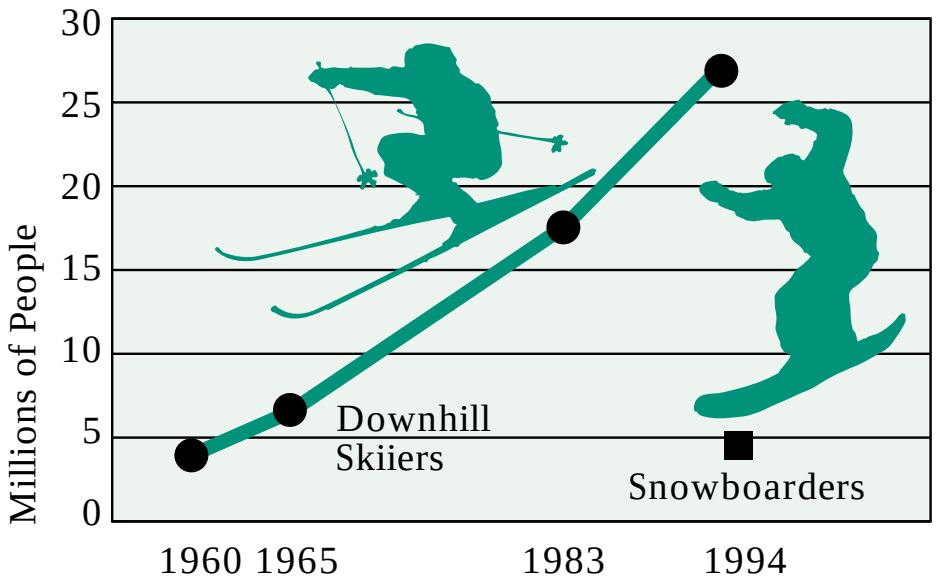


Figure 1. Growth of downhill skiing and snowboarding.

would not be ***biased***, a computer generated a list of numbers that were used as telephone numbers. Dr. Cordell telephoned people in every State in the United States and asked them questions about whether or not they went downhill skiing or snowboarding. If they had done either activity, he asked them how many times they had gone in the past year. To know more about them as people, he asked for ***demographic*** information, such as their sex, age, occupation, and ***income***.

Reflection:

- Why should a social scientist guard against being biased when choosing the people to ask questions of? What would happen to the results if the research were biased?
- Why do you think the scientist wanted to know the demographics of people who went skiing or snowboarding?

Results

The scientist found that 8.4 percent of Americans over age 16, or 16.8 million people, went downhill skiing in the previous year. He also found that 2.3 percent of Americans, or 4.5 million people, went snowboarding. On the ***average***, skiers went skiing 7.5 days a year. If you add up all the days that Americans went skiing, you get 126.5 million days! Dr. Cordell discovered that 74 percent of all skiers really love to go skiing. These people also ski often. The other 26 percent of skiers do not go skiing very often. The people who love to go skiing and snowboarding the most are under age 50.

The scientist was also interested in skiing ***trends***. He compared the number of people who went skiing in the last year with the number reported in a similar study conducted 10 years ago. Dr. Cordell estimated that downhill skiing had increased in popularity by 58 percent. 10 years ago, few people knew about snowboarding, so the scientist was not able to calculate a trend for it *(Figure 1)*. The scientist discovered that most skiers are white males, although white women ski more than people of color. He also found that as incomes rose, people were more likely to go skiing.

Reflection

- Do you think that 8.4 percent of the people in your community go skiing? Why or why not?
- Do you think that 8.4 percent of the people in Texas go skiing?
- What does that tell you about the value of averages?
- When will the scientist be able to calculate a trend for snowboarding?

Implications

Downhill skiing is a very popular outdoor recreation activity. Agencies like the USDA Forest Service and companies that own ski resorts or manufacture ski equipment should plan for a continued increase in skiing in the future. Snowboarding,

which now only has a small number of participants, will also be an important part of the downhill skiing business in the future.

Reflection

- Why do you think that more and more people are going skiing?

- What are some other ways to find out how many people go skiing?

From: Cordell, H. K. (1999). *Outdoor recreation in American life: A national assessment of demand and supply trends.* Sagamore Publishing.

Discovery FACTivity

The scientist in this study used a questionnaire to discover information. But, because he could not ask everyone in the United States his questions, he selected a sample. If the sample is not biased, it should represent the whole population. In this FACTivity, we are going to discover whether a sample of your class can represent the whole class.

First, identify a sample of students in your class. You don't want to be biased, so all students must have the same chance of being selected. You can do this by writing the name of each student on a piece of paper. Put all the names into a hat or bowl and mix them up. You will select a sample that is 50 percent of the class size. Calculate how many names you will pull from the hat by taking the total number of students and multiplying it by .50.

Skiing is a popluar sport.

Before you pull the names, however, we'll need to get some answers from everyone in your class! Have everyone take a sheet of paper and write their name on it. Then, they should write the answers to the following questions on the page:

1. Are you a boy or a girl?

2. Did you ride your bicycle in the last year?

3. Did you play soccer in the last year?

With the help of your teacher, count the number of responses to each question. Then, calculate the percentage that each represents. For example, pretend your total class size is 24 and there are 14 girls in the class. If you divide 14 by 24 you get .58 or 58 percent of your class are girls. If 20 people in your class rode their bicycle in the last year, you will divide 20 by 24 to get .83. That means 83 percent of you rode your bicycle in the last year.

Next, pull names from the hat or bowl. Now you will calculate the responses to each question, but this time you will only use the responses of the students whose names were pulled. For each response to the three questions, calculate the percentage. You will not divide the responses by the total class size, but by a number half of the class size. Then, compare the percentages calculated for each question in the sample with the percentages calculated for the whole class. Are they similar? You should not expect them to be exact. If they are not similar, try again by putting all the names back into the hat and pulling another 50 percent sample. If you continue to pull 50 percent samples, most of the sample responses will be similar to the class as a whole. When scientists use samples, they know they will not be exact. However, they feel that their findings are close enough to give them information about the whole population.

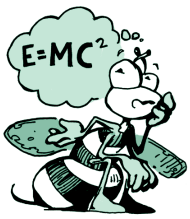
For more information see: www.srs.fs.fed.us/recreation

Go With the Flow!

Are Mountain Stream Channels Shaped by Flood and Drought?

Meet Dr. Sandra Ryan

"I like being a scientist because I like to solve problems."



Thinking About Science...

When scientists develop plans to do research, those plans influence and limit what they will discover. If a scientist decides to measure something, that is all he or she can report about. For example, the scientist in this study wanted to know whether streams changed from their normal shape when water was *diverted* from them and into another *channel*. To find this out, she measured the width of the streams' channels. After the research was done, she reported that she should have also measured the channels' depth and the size of the stones in the channels. Because she did not measure those things, she could only report on changes in the channels' width. A scientific study does not always provide the complete answer to a question. It often raises other questions that can be addressed in future research.

Thinking About the Environment...

When humans make changes in the environment, they are not always sure what impact those changes will have on the environment. In this study, the scientist wanted to know if steep mountain stream channels are changed by diverting water from them. In the Western United States, water is often *scarce* where people live. To provide water for people living in cities where water is scarce, it is diverted from mountain streams. It is piped through tunnels across the mountains to *reservoirs* for storage and human use. When this is done, the existing mountain streams have a reduced flow, and sometimes may even be dry.

Introduction

When humans divert water from mountain streams, there is less water in the streams at certain times. *The scientist in this study wanted to know whether stream channels are changed as a result of having*

Dr. Sandra Ryan

less water at certain times, and normal flow at other times. Because most earlier research had been done on flatter, wider streams, not much was known about how channels change when water is diverted away from steep, narrow mountain streams. Melting snow creates most of the stream flow, and this flow can be heavy for days or weeks when snow is melting. When there is a lot of melting snow, water overflows the *diversion dam* and briefly flows again down the stream channel at a normal flow. *The scientist wanted to know what happens to the channel when water is diverted out of it.* Does vegetation begin to grow along the banks of the channels? What happens when water fills the stream channel again, during periods of high snow melt or rainfall? These are the questions Dr. Ryan, the scientist in this study, wanted to answer.

Reflection

- What human needs are being met by diverting water from a stream channel and into a reservoir? Can you think of 10 ways that humans use water?

- What kind of changes do you think occur in a stream channel if the water is diverted out of it?

Methods

The scientist collected information from two main sources to answer her question. First, she identified which streams she wanted to study. She wanted to compare the channels of free-flowing streams with similar stream channels that had been diverted. Dr. Ryan and her colleagues then went to the stream channels and took measurements in person *(Figure 1)*. She identified the stream channel as free-flowing or diverted. Then, she measured the width of all of the channels. Once she knew the widths of the stream channels, she used existing measurements on water flow in these streams to identify how much water was diverted from these stream channels over the years. The existing measurements had already been taken by others and were recorded in a computer.

Reflection

- Why did the scientist compare stream channels that had most of the water diverted from them with free-flowing stream channel widths?

- What are the advantages of using existing measurements to help answer a research question? What are the disadvantages?

Glossary:

channel:
(chan'el) the bed of a stream or waterway

diversion dam:
(di vûr'zhen dam) a barrier used to divert stream water from its regular channel

divert:
(di vûrt') to turn aside or draw off from a path or course

periodically:
(pêr'ê od'i kel lê) occurring at regular intervals

reservoir:
(rez'er vwär) a place where water is collected and stored for use

scarce:
(skârs) not plentiful or abundant

Figure 1. Measuring the stream channel.

Results

Dr. Ryan estimated that the diverted stream channels had been reduced in water flow from between 19 percent to 60 percent *(Figure 2)*. This reduction was considered significant. This means that, when comparing diverted-flow streams to free-flowing streams, the difference is greater than what might have occurred simply by chance. She also found that during years with little snowfall, the diverted streams almost went dry. In years with high snowfall, less water is diverted. In those years, the diverted stream channels were allowed to flow as they would have flowed without being diverted.

During dry years, vegetation often begins to grow along diverted stream channels, changing the channels' shape. However, during periods of high water, the water's "normal" flow erases many of these changes. Dr. Ryan concluded that changes in these diverted stream channels can hardly be noticed. Even though the changes can hardly be noticed, Dr. Ryan is cautious about concluding that diverting water out of mountain stream channels does not cause changes in the channels. She noted three reasons for being cautious: 1) If there are many years in a row without a lot of snowfall, more changes might be observed; 2) The channel surfaces of mountain streams are very stable, and the changes might be occurring more slowly than she could measure with the information available; and 3) Changes in mountain channels might be more detectable if something other than the width were measured. Dr. Ryan suggested that a description of the channel bed, and the depth of the stones in the channel, might be a better indication of change.

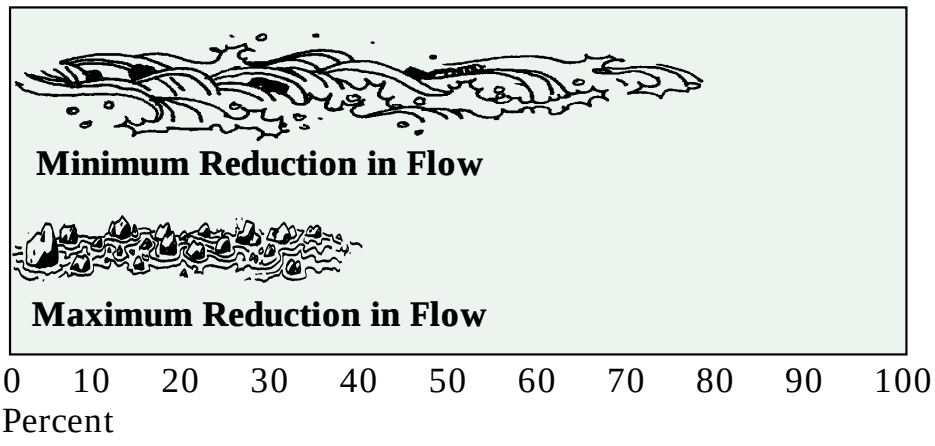


Figure 2. Maximum and minimum flow.

Reflection

- What is the danger of concluding that diverted stream channels are not changed by diverting water out of them?

- What other kinds of changes might be occurring in and around the diverted stream channels? (Hint—Think about the animals that depend on water for survival.)

Implications

Because people will continue to live in cities that are located in dry climates, we will continue to divert water from streams and into reservoirs. To make sure that mountain stream channels are not changed by diverting water from them, managers should allow water to flow normally in them *periodically*. In addition, further study is needed to determine the impacts of water diversion on water-dependent species, such as fish and frogs.

Reflection

- What might happen to fish and frogs in years where there is little snowfall?

- How would you study the impact of water diversion on fish?

- Can you think of any other actions humans can take to reduce the impact of stream diversion on animal species?

From: Ryan, Sandra (1997). Morphologic response of subalpine streams to transbasin flow diversion. *Journal of the American Water Resources Association, 33(4),* 839–854.

Discovery FACTivity

Streams and rivers get their water from rainfall and melting snow. Water flows downhill because of gravity, and eventually flows into the oceans. Vegetation near streams and rivers helps to hold soil in place, keeping it from being carried by rainfall and melting snow into streams and rivers. When vegetation near streams and rivers is disturbed or removed, it can no longer hold the soil in place. When this happens, soil may flow into streams and rivers. What activities might cause vegetation to be disturbed near streams and rivers?

Line an 18"x24" cardboard box with plastic. Place an oblong bowl, such as an aluminum foil roasting pan, at one end. Fill around the bowl with soil, and build up the soil in the rest of the box. Shape the soil so that you are creating a hill. The top of the hill is at one end of the box, and the bottom is at the other end, where the bowl is. Create a small channel, like a stream, from the top of the hill down to the bowl. It can have curves, just like a stream. The channel should be lower than the surrounding soil, and the soil should gently slope toward the channel. Get pebbles and small rocks and place them in the channel. See Figure 3. The channel represents a stream, and the bowl represents a pond. Now, get a watering can with a sprinkler head (the kind with small holes in it). Using the watering can, water the soil at the top of the hill. When you water, you are simulating rainfall. Be sure not to water more than the pond can hold!

Observe what happens to the soil as the water falls. Does it stay in place? If not, where does it go? When human activities and natural events cause vegetation to be disturbed near streams and rivers, what do you think happens to the soil? Do you think this is good for the land and streams or rivers? Why or why not?

For more information, see: www.xmission.com/~rmrs/staffs/labs/laramie/lar_rm4352.html

Figure 3. Setup for FACTivity.

Students—Tell Us What You Think About The Natural Inquirer

Please photocopy this form for each article you read and complete these evaluation forms. Send them to the address below.

1. The article I read was:

☐ Quit Yer Horsin' Around

☐ Slip Sliding Away

☐ Finding Ways to Soak Up the Rays

☐ Quaking in Their Roots

☐ Are We Having Fungi Yet?

☐ There Goes the Neighborhood

☐ Go With the Flow

Circle or check the answer that best describes how you feel about the article you just read.

2. The article was:

☐ Very easy to understand

☐ Easy to understand

☐ Hard to understand

☐ Very hard to understand

3. The article was:

☐ Very interesting to read

☐ Interesting to read

☐ Somewhat interesting to read

☐ Not interesting to read

4. Did you learn something from reading the article? ☐ Yes ☐ No

5. Did you try to answer the Reflection Questions? ☐ Yes ☐ No ☐ Some of them

If you read and tried to answer the Reflection Questions, did they help you to think about the article? ☐ Yes ☐ No

6. Would you like to read another article?

☐ Yes ☐ No

7. How old are you? *(Circle)*

10 11 12 13 other age: _____

8. What grade are you in? *(Circle)*

4th 5th 6th 7th

9. Are you a girl or a boy?

☐ Girl ☐ Boy

Now write in your answer:

10. What did you learn from reading the article?

_____

_____

_____

_____

_____

_____

_____

11. What is your favorite subject in school?

_____

_____

Please send to:
Dr. Barbara McDonald
USDA Forest Service
320 Green St.
Athens, GA 30602-2044

Thank you!

Teachers—Tell Us What You Think About The Natural Inquirer

Please photocopy this form for each article you read and send the completed evaluation forms to the address below.

For each article that you read, please answer the following:

Name of Article:_____

1. Would this article help you meet any of the required statewide science curriculum standards? ☐ Yes ☐ No

2. How close to the appropriate reading and comprehension level for your students is this article written?

☐ Very close

☐ Somewhat close

☐ Not close

3. If the article is somewhat close or not close to the appropriate reading and comprehension level, is it:

☐ Too hard

☐ Too easy

4. Will you use this article in your classroom as an educational resource?

☐ Yes ☐ No ☐ Why or why not?

_____

_____

_____

_____

5. Please rate the article sections on a scale of 1 to 5. One means the section was not useful at all, five means the section was very useful.

	Not useful				Very useful
Meet the Scientist	1	2	3	4	5
Glossary	1	2	3	4	5
Discovery FACTivity	1	2	3	4	5
Thinking About Science	1	2	3	4	5
Thinking About the Environment	1	2	3	4	5
Introduction	1	2	3	4	5
Methods	1	2	3	4	5
Results	1	2	3	4	5
Graphs, figures, photos	1	2	3	4	5
Implications	1	2	3	4	5
Reflection Sections	1	2	3	4	5

6. Was the "Project 2061/National Science Curriculum" matrix useful to you?

☐ Yes ☐ No ☐ Somewhat

7. Was the "Note to the Teacher" useful to you?

☐ Yes ☐ No ☐ Somewhat

8. What grade(s) do you teach? _____

9. What subject(s) do you teach?

_____

10. What is your zip code? _____

More on page 36 ☞

11. For any of the sections you rated with either a "one" or a "two" in question 5, please indicate why the section was not useful or how it can be improved:

Meet the Scientist

Glossary

Discovery FACTivity

Thinking About Science

Thinking About the Environment

Introduction

Methods

Results

Graphs, figures, photos

Implications

Reflection Questions

12. Other comments or suggestions:

Please send to:
Dr. Barbara McDonald
USDA Forest Service
320 Green St.
Athens, GA 30602-2044

Thank you!

Which National Standards* Can Be Met by The Natural Inquirer?

**From Project 2061—American Association for the Advancement of Science Articles*

Standards	Quit Yer Horsin' Around!	Slip Sliding Away	Finding Ways to Soak Up the Rays	Quaking in Their Roots	Are We Having Fungi Yet?	There Goes the Neighborhood!	Go With the Flow
Scientific Enterprise	X	X	X		X	X	X
Scientific Inquiry	X	X		X		X	X
Processes That Shape the Earth	X			X		X	X
Communication Skills	X	X	X		X	X	X
Critical Response Skills	X	X	X			X	X
Reasoning							X
Interdependence of Life				X			X
Technology and Science	X	X					
Issues in Technology	X	X		X	X	X	
Political and Economic Systems		X					
Uncertainty/Computation & Estimation		X					
Social Tradeoffs	X						X
Constancy and Change				X			X
Cultural Effects on Behavior		X					
Shapes		X					
Regulation and Behavior			X				
Symbolic Relations			X				
Science Values and Attitudes			X				
Diversity of Life				X			
Mathematics, Science & Technology				X	X		
Heredity				X			
The Nature of Mathematics						X	
Values and Attitudes						X	
Mathematical Inquiry					X		
Systems				X		X	X
Additional Standards Met *(From the National Science Foundation)*							
Natural Hazards					X	X	X
Populations and Ecosystems			X				
Reproduction and Heredity				X			
Diversity & Adaptation of Organisms						X	

What is the Forest Service?

The Forest Service is part of the Federal Government. It is made up of thousands of people who care for the Nation's forest land. The Forest Service manages over 150 national forests and almost 20 national grasslands. National forests are similar in some ways to national parks, except that unlike national parks, national forests are used for many purposes. These purposes include providing clean water; places for wildlife and fish; places for people to hike, camp, and do other outdoor activities; healthy soil; trees for lumber; and minerals. Some people in the Forest Service are natural resource scientists, whose research is presented in this journal. Forest Service scientists work to solve problems and provide new information about natural resources so that we can make sure our environment is healthy, now and into the future.

The U.S. Department of Agriculture (USDA) prohibits discrimination in all its programs and activities on the basis of race, color, national origin, gender, religion, age, disability, political beliefs, sexual orientation and marital or family status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication of program information (Braille, large print, audiotape, etc.) should contact the USDA's TARGET Center at 202-720-2600 (voice and TDD).

To file a complaint of discrimination, write the USDA Director, Office of Civil Rights, Room 326-W, Whitten Building, 14th and Independence Avenue, SW, Washington, DC 20250-9410 or call 202-720-5964 (voice or TDD). USDA is an equal opportunity provider and employer.

United States Department of Agriculture

Forest Service

Visit these websites for more information:

USDA Forest Service:
www.fs.fed.us

The Natural Inquirer:
www.fs.fed.us/research/natural_inquirer.htm

Conservation Education:
www.fs.fed.us/outdoors/nrce/

Rocky Mountain Research Station:
www.xmission.com/~rmrs/

NatureWatch:
www.fs.fed.us/outdoors/naturewatch/default.htm

Woodsy Owl:
www.fs.fed.us/spf/woodsy

Smokey Bear:
www.smokeybear.com

National Forest Information:
www.fs.fed.us/links/forests.shtml

National Forest Recreation:
www.fs.fed.us/recreation/recreation.shtml