NATURAL INQUIRER

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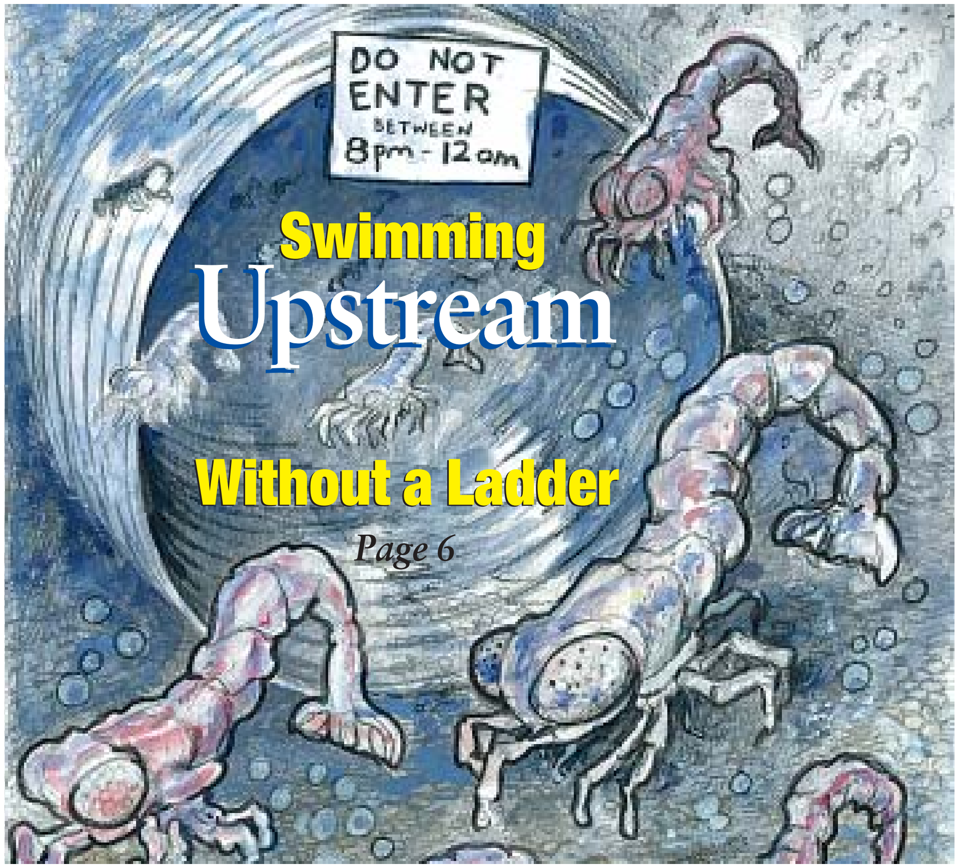

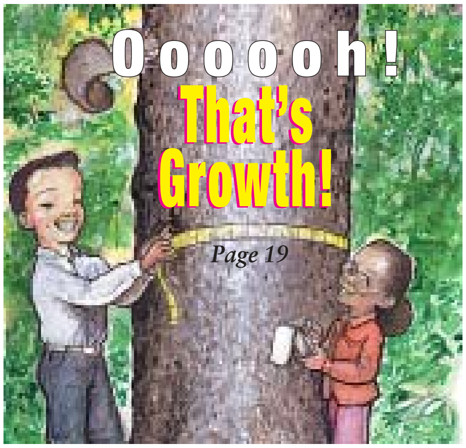

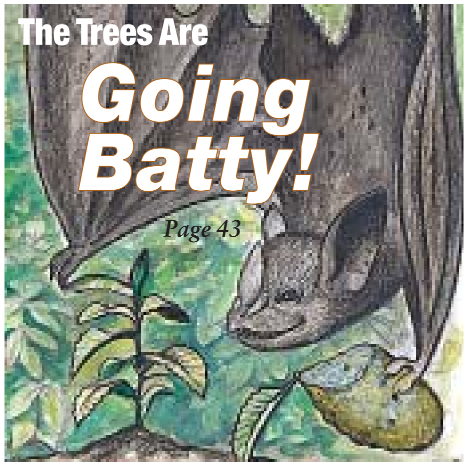

The Natural Inquirer
Volume 3, Number 1
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Tropical Forest Edition

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Teacher's Note

As teachers of science, one of your goals is to teach students the scientific method, no matter what your area of focus—life sciences, Earth sciences, etc. The scientific method can best be taught by focusing on hands-on and minds-on inquiry and investigation. This allows the learner to be independent and to seek answers to questions throughout the world we live in. As educators, you are constantly faced with engaging your students in scientific inquiry in new and different ways. Standard teaching strategies can become monotonous to today's learners in an age of abundant technology. The *Natural Inquirer* gives a fresh approach to science and a view of the outside world bigger than the classroom that can be used while still in the school setting.

The *Natural Inquirer* is a science education resource journal to be used with learners in Grade 5 and up. The *Natural Inquirer* contains articles describing environmental and natural resource research conducted by Forest Service scientists and their cooperators. These are scientific journal articles that have been reformatted to meet the needs of an audience new to science. The articles are easy to understand, are aesthetically pleasing to the eye, contain glossaries, and include hands-on activities. The goal of The *Natural Inquirer* is to stimulate critical reading and thinking about scientific inquiry and investigation while learning about ecology, the natural environment, and natural resources.

Past issues and articles from The *Natural Inquirer* are available by visiting the Web site at http://www.naturalinquirer.usda.gov.

Science Education Standards:

In the back of the journal, you will find a matrix which allows you to identify articles by the national science education standards that they address.

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Teacher's Manual:

Please visit *The Natural Inquirer* Web site at http://www.naturalinquirer.usda.gov. From this site, you may read the teacher's manual online, download it, or request a hard copy.

Visit http://www.naturalinquirer.usda.gov for previous issues of the *Natural Inquirer,* sample lesson plans, word games, the teacher's manual, information about the Forest Service, and other resources.

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Features

The *Natural Inquirer* is reproduced on recycled paper with soy-based inks.
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About 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 Forest Service. If you want to know more about the Forest Service, you can read about it on the back cover of this journal, or you can visit the *Natural Inquirer* Web site at http://www.naturalinquirer.usda.gov.

All of the research in the *Natural Inquirer* is concerned with nature, such as trees, forests, animals, insects, outdoor activities, and water. First, you will "meet the scientist" who conducted the research. Then you will read something special about science and about the natural environment. You will also read about a specific research project. This is written in the format that scientists use when they publish their research in journals. Then, YOU will become the scientist when you conduct the FACTivity associated with each article. Don't forget to look at the glossary and the section called "Thinking About Ecology." By thinking about ecology, you will learn about principles that apply to all life, including yours!

At the end of each section of the article, you will find a few questions to help you think about what you have read. These questions are not a test! They should help you to 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. Some scientists study the natural environment. To be a successful environmental scientist, you must:

- **Be curious—**You must be interested in learning.
- **Be enthusiastic—**You must be interested in an environmental topic.
- **Be careful—**You must be accurate in everything that you do.
- **Be open minded—**You must be willing to listen to new ideas.
- **Question everything—**You must think about what you read and observe.

Scientists in this issue at work.

Welcome to the *Natural Inquirer* Tropical Forest Edition

This edition of the *Natural Inquirer* describes forest and environmental research conducted in the tropical region of the Western Hemisphere (See Figure 1). The tropics is a region near the equator, between 23.5° north latitude, and 23.5° south latitude. Latitude is measured by parallel imaginary lines ringing the Earth. The tropical region gets a lot of sunshine and is warm all year around, except in the high mountain regions (See Figure 2). The tropics are the home of a variety of biomes (**bi** oms), or regions with different kinds of vegetation and other life. Tropical biomes are largely defined by the amount of rainfall they get. In the tropics, you might find rain forests, dry forests, shrub lands, tropical plains called savannahs (sä **van** uhs), and deserts.

The research in this *Natural Inquirer* was conducted by scientists working in the International (**in** tür **na** sha nul) Institute of Tropical Forestry, or IITF (Figure 3). IITF is located in Puerto Rico, a tropical island in the Caribbean Sea. The IITF conducts research to help keep tropical forests healthy now and into the future, to help protect the animals that live in the forests, and to take care of streams and rivers and the forests around them. IITF is a part of the Forest Service. You can learn about the Forest Service on the back cover of the *Natural Inquirer*, or by visiting http://www.naturalinquirer.usda.gov and clicking on "About the Forest Service."

Figure 1. This issue presents research conducted in Puerto Rico, the U.S. Virgin Islands, Costa Rica, the Dominican Republic, and Brazil.

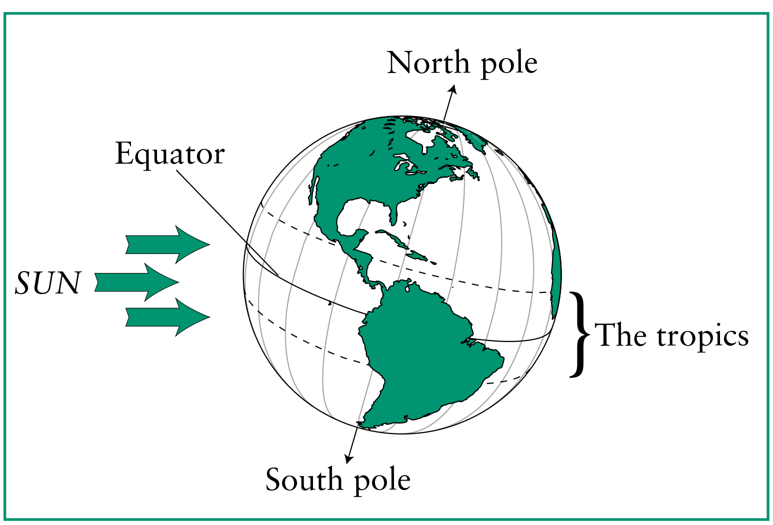


Figure 2. Illustration of the location of the sun in relation to the tropics.

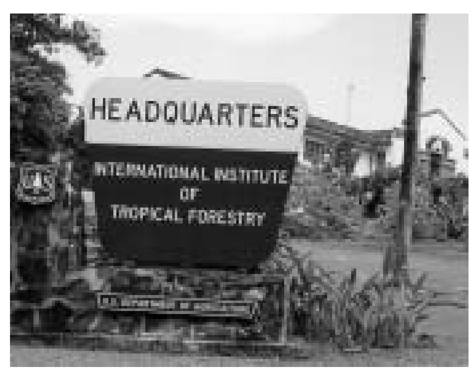


Figure 3. International Institute of Tropical Forestry.


DO NOT
ENTER
BETWEEN
8pm - 12am

Swimming Upstream Without a Ladder:

Dams and Pipes and River Shrimp Movements

Meet Dr. Benstead:

I like being a scientist because I am excited about the natural world and want to help *conserve* it for future generations to enjoy.

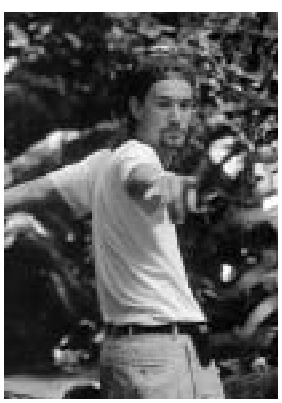
Dr. Benstead

Meet Dr. Pringle:

Dr. Pringle

I like being a scientist because I like working outside, in the stream, getting my feet wet. I also like doing research that will help conserve the environment.

Meet Dr. March:



Dr. March

I like being a scientist because I enjoy learning how natural systems work. Also, for part of the year my office is a beautiful stream!

Meet Dr. Scatena:

Dr. Scatena

I like being a scientist because I like the challenge of trying to understand how natural systems work so that we can manage and preserve them for future generations.

Glossary:

conserve (kän **sürv**): To avoid wasteful or destructive use of something.

species (**spe** sez): Groups of organisms that resemble one another in appearance, behavior, chemical processes, and genetic structure.

migrate (**mi** grat): To move from one place to another.

larval (**lär** väl): Relating to the wormlike feeding form that hatches from the egg of many insects or animals that changes form when it becomes an adult.

tropical (**träp** i käl): Of, in, or like the tropics. The tropics is the region of the earth near the equator.

maturity (muh **toor** uh te): The state of being fully grown or developed.

ecosystem (e ko sis tem): Community of plant and animal species interacting with one another and with the nonliving environment.

dependent (duh **pen** dent): Relying on.

algae (**al** je): Simple plants that have no true root, stem, or leaf and that usually grow in water or on damp surfaces.

population (päp yoo **la** shun): The whole number of individuals of the same type occupying an area.

life cycle (lif **si** kul): Stages in the development of an organism.

fish ladder (fish **lad** er): A series of small dams built in streams or rivers. These function like steps to enable animals to swim upstream.

simulate (**sim** yuh lat): To create the appearance or effect of something for purposes of evaluation.

analyze (**an** uh liz): To study or examine carefully.

Pronunciation Guide

a	as in ape	ô	as in for
ä	as in car	u	as in use
e	as in me	ü	as in fur
i	as in ice	oo	as in tool
o	as in go	*ng*	as in sing

Accented syllables are in **bold**.

Thinking About Science

Although scientists sometimes work alone, they usually do their research with other scientists. Even if they live in different areas of the Nation or the world, they find ways to work together. In this study, scientists from the University of Georgia worked together with a Forest Service scientist in Puerto Rico to study a special kind of shrimp. In your classroom, you sometimes work with other students. When you do this, you are like a scientist who works with other scientists. Can you name two reasons why it is a good idea to work with others when you are learning something new?

Thinking About the Environment

Many animal *species* spend part of their life in one location and part of it in another place. When that happens, the animal is said to be migratory. Animals usually *migrate* to a place more favorable for reproduction. People often think of birds when they think of migratory animals. In this study, the migratory animal is a river shrimp. When it is in its *larval* stage, the shrimp larvae drift from streams in high *tropical* mountains to areas near the coast. There they grow beyond the larval stage. When they are ready to become adults and reproduce, the juvenile shrimp swim back upstream to where they were born. When the juveniles encounter barriers such as waterfalls, they crawl over them to continue their upstream journey. When they get upstream, they grow into adult shrimp and reproduce. Their offspring drift back downstream with the current, and the cycle begins again.

Introduction

Tropical streams provide many benefits to people and animals. For river shrimp that spend part of their life in the mountain streams, the streams provide a place to reproduce and develop. River shrimp are important to the streams as well. They eat the *algae* in the streams and help to turn dead matter, such as fallen leaves, into small particles. When they swim and crawl in the streams, they stir up the water. This enables the stream to wash away any soil and other things that may have settled into the stream bed.

Thinking About Ecology

In an area, the individuals of a species live in close relationship with other living things and with the nonliving environment. This relationship determines how many individuals there will be, how fast they will grow, and how many individuals of different ages there will be at any one time. Living communities plus the nonliving environment make up what we call an ecosystem. Humans often alter the nonliving environment. This alteration can affect a species by changing their numbers, changing how fast they grow, and changing how many different individuals there will be of different ages. In this research, a species of river shrimp was studied. The shrimp depend on both mountain rivers and coastal wetlands to live and reproduce. Humans had altered the river environment by building a dam and placing a pipe to carry water from the river to provide water for humans. Because all living individuals have a close relationship with their environment, any change in the environment can cause a change in the life of the individual and the group of individuals. The scientists wanted to know how the dam and pipe were affecting the river shrimp, which must move up and down the river to survive.

Figure 1. Dam on the Río Espíritu Santo in Puerto Rico.

Tropical streams also provide people with the fresh water they need for drinking, cooking, and washing. Because more and more people are living in tropical areas, more water is needed. To provide water for people, small dams are often built in tropical streams (Figure 1). This creates a small pool of water. The water is diverted from the small pool into a pipe that carries the water to cities where people use it. Unfortunately, the pipe also carries many of the shrimp larvae out of the stream. That means fewer larvae are able to get downstream to the coastal zone. When the juveniles swim back upstream, the dams can sometimes prevent them from swimming far enough. When that happens, the shrimp cannot reproduce. In this way, the population of shrimp is reduced more and more over time. The scientists in this study wanted to find a way to protect the shrimp population while continuing to provide water for people.

Reflection Section

- If the scientists do not find a way to protect the shrimp population and still provide water for people, what do you think will happen to the shrimp population in the future?
- If you were the scientist, how would you study the population of migrating shrimp?

Method

The scientists studied a mountain stream near a dam on the Rio (**re** o) Espiritu (eh **sper** eh tu) Santo (**sän** to) on the Caribbean (kä **rib** e un) National Forest in Puerto Rico (Figure 2). To find out how many shrimp larvae were flowing into the pipe, the scientists put nets into the water. First, they put nets in the water above the dam and counted the total number of larvae floating downstream. They also put a net in front of the pipe and counted the number of larvae in their net. From this method, they knew how many larvae would have flowed into the pipe and how many would have floated over the dam. To find out how many juvenile shrimp were returning upstream, the scientists put a net into the water below the dam. They counted the number of juveniles below the dam by counting how many were caught in the net. Because shrimp larvae float downstream in the evening and at night, the scientists collected their information in the evening and at night. They collected information every third evening, for a total of 24 evenings.

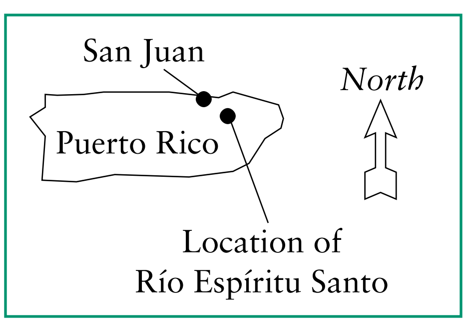


Figure 2. Location of the Rio Espiritu Santo.

Reflection Section

- Instead of collecting their information on just one evening, the scientists counted the number of shrimp larvae on 24 evenings. Why do you think it is important to count the number of larvae on more than one evening?
- How do you think that the scientists knew that shrimp larvae float downstream during the evening and night, rather than during the daytime?

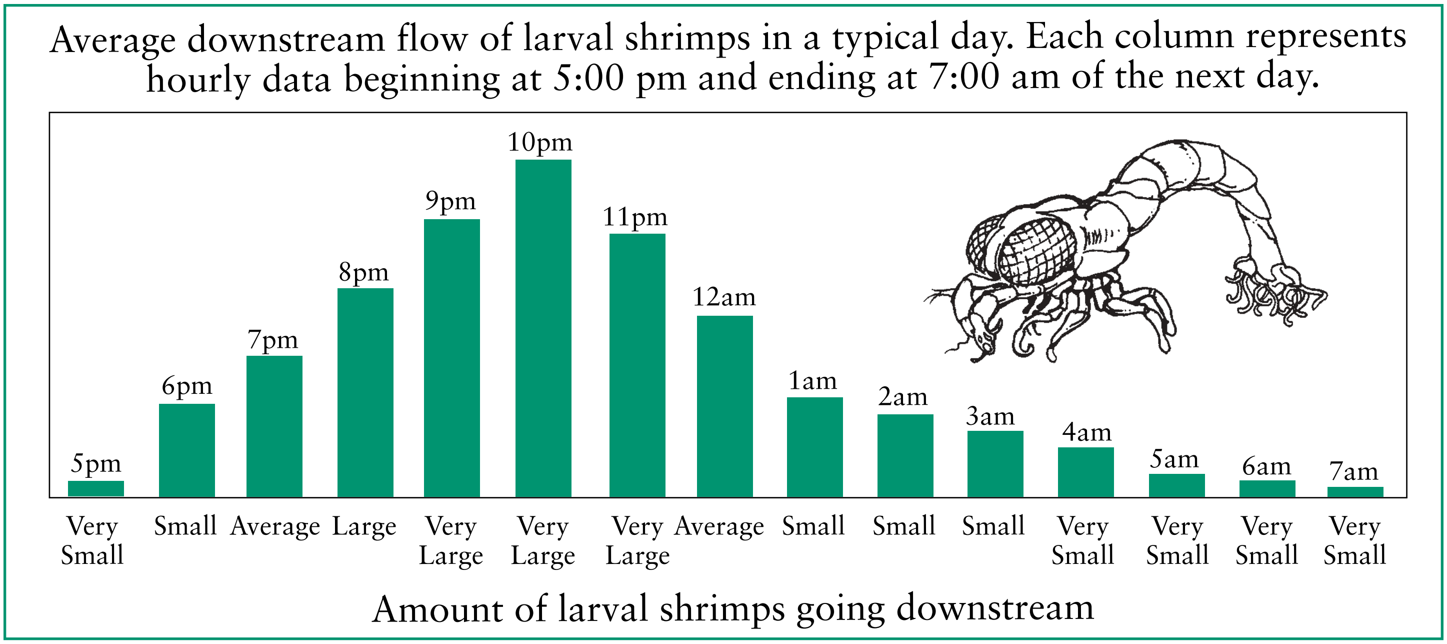


Figure 3. The average amount of shrimp larvae floating downstream at different times of the day.

Results

The scientists discovered that most shrimp larvae float downstream between 8:00 p.m. and 12:00 a.m. (Figure 3). The average percentage of larvae floating into the pipes was 42 percent of the total number of larvae floating downstream (Figure 4). The scientists also found that the dam often prevented the juvenile shrimp from swimming upstream. This meant that many juvenile shrimp were trapped below the dam, waiting for a chance to climb over the dam. With so many waiting below the dam, fish who feed on the juvenile shrimp were able to eat larger numbers of the young shrimp than they normally would have.

Reflection Section

- In what ways did the dam and pipe disrupt the normal *life cycle* of river shrimp? What other things (animals, plants, or the stream itself) were impacted as a result of this?
- How could the scientists' information be used to help the river shrimp? What do you think the scientists recommended?

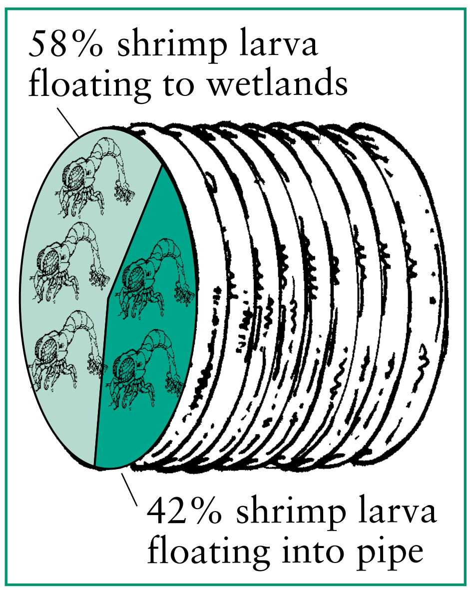


Figure 4. The average percentage of shrimp larvae floating into the pipe and down to the wetlands.

Implications

The scientists recommended that the water pipe be closed every evening between 8:00 p.m. and 12:00 a.m., or at least for some of the hours when most of the larvae are floating downstream. That way, most of the shrimp larvae could float downstream to the wetlands without getting caught in the pipe. In addition, people would still be able to use the water from the streams. The scientists also recommended that the small *fish ladder* that had been built be repaired so that river shrimp could use it again (Figure 5). That way, the juvenile shrimp could climb over the fish ladder to get back upstream. If these recommendations are not followed, the population of fresh water shrimp will probably continue to decline in tropical streams where dams exist.

Figure 5. Fish ladder on the Río Espíritu Santo. The fish ladder is on the far right, below the people. It looks like a ramp in this photo.

Reflection Section

- Although the scientists' suggestions may help protect the shrimp population and still allow people to use the stream water, some people may not want to follow the suggestions. Can you think of reasons why people may not want to follow these suggestions? (Hint: Everything costs money to build and take care of. Who would pay for the fish ladders?)

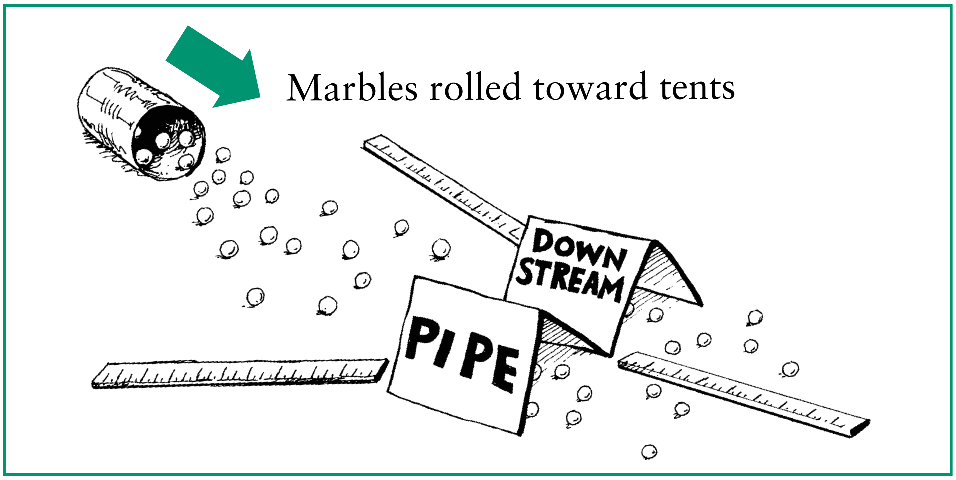
- Do you think that the scientists' suggestions are a good compromise between protecting the river shrimp and providing water for human use? Why or why not?

Discovery FACTivity

For this FACTivity, you will answer the question: What is the difference between having a 50 percent chance of having something happen, and having less or more than a 50 percent chance? You will use marbles to show how some river shrimp get caught in the pipes, and other shrimp are able to drift downstream. In the study you just read, each shrimp had just over a 40 percent chance of floating into the pipe, and almost a 60 percent chance of floating downstream (that means that if 10 shrimp were floating downstream, 4 would go into the pipe, and 6 would float downstream). Look again at Figure 4. Fortunately for the shrimp, each one had better than a 50 percent chance of drifting downstream.

In this FACTivity, each shrimp will have a 50 percent chance of floating into a pipe, and a 50 percent chance of floating downstream. Each station that you construct will *simulate* a stream with a pipe. You may make three or four identical stations, with six to eight students per station. For each station, you will need 3 yardsticks, 1 piece of 22- by 28-inch posterboard, 100 marbles, and a coffee can. Cut the posterboard along its width into two equal-sized pieces and fold each piece in half to make tents. Write "downstream" on one tent, and "pipe" on the other. Place the tents side by side, and lay one yardstick on each side of the tents. Place the third yardstick between the tents, at the back (see diagram on page 12).

Three students will be stationed behind the tents. One student will catch and count the marbles coming through one tent, the other will catch and count the marbles coming through the other tent. A third student will record the number of marbles coming through each tent. You may use the chart below as an example to record your observations. Place the 100 marbles (simulating 100 shrimp) in the coffee can. Another student, standing about 6 feet (or 2 meters) back, will gently roll the marbles toward the tents. The student should aim for the center of the tents. Do not roll them too hard—remember, they are shrimp floating downstream! The students behind the tents should catch and record the number of shrimp floating "downstream" and the number floating into the "pipe." The shrimp that floated into the pipe will die. The shrimp that floated downstream should be taken back upstream and rolled toward



the tents again. Every time you roll the marbles, the marbles represent the offspring of the shrimp that successfully returned upstream to reproduce. Continue to roll the marbles until all of the shrimp have died (rolled into the pipe). Now that you have made and recorded your observations, you will need to *analyze* them. Calculate the percentage of shrimp going into the pipe each time. How many times does it take for all of the shrimp to drift into the pipe? Now calculate the average percentage going through the pipe by adding the numbers in second column and dividing them by the number of rolls. This tells you the overall average percentage of shrimp drifting through the pipe.

Record the average percentage of your shrimp drifting through the pipe. Compare your percentage to the percentage that the scientists found in their study (42 percent). Why do you think your percentage is different than 42 percent? What is different about your experiment and the stream's flow? If you rolled your marbles straight down the middle, your overall percentage should have been close to 50 percent. Was it? If not, what may have caused your percentage to be different? Why do you think each shrimp in the Rio Spiritu Santo had better than a 50 percent chance of drifting past the pipe?

Sample form for recording your observations. Begin with 100 marbles

	# through pipe	% through pipe	# floating downstream	% floating downstream
1st roll	32 (for example)	32 or .32	68	68 or .68
2nd roll	Begin with 68 marbles – Record #	# through pipe divided by 68	Subtract number through pipe from 68	Divide # floating downstream by 68
3rd roll	Begin with # floating downstream			
4th roll				
5th roll				
6th roll				
7th roll				
8th roll				
9th roll				
10th roll				

From Benstead, Jonathan P., March, James G., Pringle, Catherine M. and Scatena, Frederick N. (1999). Effects of a low-head dam and water abstraction on migratory tropical stream biota. *Ecological Applications*, 9(2): 656-668.

Leaf Me Alone!

The Movement of Nutrients Between Trees and the Soil

Meet Dr. Cuevas:

I like being a scientist because I get to discover new things about the natural environment.

Dr. Cuevas

Meet Dr. Lugo:

I like being a scientist because it brings me into contact with people who, like me, are fascinated by the *complexity* of nature and have an opportunity to try to figure it out. Then we can put the information to work for the benefit of people.

Dr. Lugo

Glossary:

complexity (käm **plek** suh te): The state of being complicated or having many related parts.

quality (**kwôl** ä te): Any of the features that make a thing what it is.

quantify (**kwän** tä fi): To count or measure; to give the quantity of.

nutrient (**noo** tre ent): Any of the substances found in food that are needed for the life and growth of plants and animals.

organism (**ôr** gä niz um): Any living thing.

decomposer (de käm **poz** ür): Organisms that digest parts of dead organisms and the wastes from living organisms.

analyze (**an** ä liz): To study or examine carefully.

species (**spe** sez): Groups of organisms that resemble one another in appearance, behavior, chemical processes, and genetic structure.

biomass (**bi** o mas): All the living things in a particular area.

external (ek **stür** nul): On the outside.

manager (**ma** ni jür): A skilled person who directs or manages something.

organic (ör **ga** nik):Related to or coming from living organisms.

Pronunciation Guide

a	as in ape	ô	as in for
ä	as in car	u	as in use
e	as in me	ü	as in fur
i	as in ice	oo	as in tool
o	as in go	*ng*	as in sing

Accented syllables are in **bold**.

Thinking About Science

Scientists use many ways to determine the *quality* of a thing. Most often, scientists use numbers to determine the amount of a particular quality a thing has. Sometimes, using numbers is not the best way to determine something's quality. For example, how could you determine how much better (a quality) your dinner tastes after you add salt to it? You would taste it and make a judgment. This judgment would be based on a comparison with how it tasted before you added salt. This is a way of determining quality without using numbers. You could *quantify* this quality of good taste by asking everyone in your neighborhood to taste your dinner before and after adding salt. Then, you could count the number of people who said it tasted better. Quality can be judged with or without numbers. Usually, scientists use numbers because numbers are less subject to individual choice or opinion, as when they measure height or weight. In this study, the scientists wanted to know the quality of leaves that fell from trees. Quality was determined by the amount of *nutrients* found in the fallen leaves. Do you think the scientists used numbers to determine quality in this case? Why or why not?

Thinking About the Environment

Food chains describe the flow of energy from one organism to another. A flow of energy occurs when one organism digests another. When this happens, some of the energy is lost to the environment. The food chain starts with green plants. Green plants are the only type of organism that can convert sunlight into food by photosynthesis (**fo̲** to̲ **sin** thä sis). In forests, some of the green plants are consumed by animals such as insects and deer, but most of them are consumed by *decomposers* as dead plant material. Decomposers include bacteria, fungi (**fun** ji̲), and small animals such as earthworms. Decomposers move nutrients from the dead plant material to the soil. Once in the soil, plants can use the nutrients for new growth. The scientists in this study wanted to know whether some kinds of fallen leaves have more nutrients than other kinds of leaves. If so, those leaves would provide more nutrients to the soil, making more nutrients available to the plants.

Introduction

You probably know that trees depend on the soil in which they are rooted. But did you know that the soil depends on trees also? By

Thinking About Ecology

What is energy? Energy is the ability to do something. Energy always behaves in the same way. The behavior of energy is described by what we call the laws of energy. Energy can take many forms, and can be transferred from one form to another. When energy is transferred, its quantity decreases. That means that the amount of energy available to do something is less. The remainder of the energy becomes scattered or spread out, usually in the form of heat. This heat energy is usually lost to the environment. This means that whenever we use energy, we always end up with less useable energy than we started with. All living things need a continual source of high-quality energy to survive. As this energy is used, low-quality heat and other waste products are added to the surroundings. Everything on Earth follows the laws of energy, including us! These are laws that no one can break.

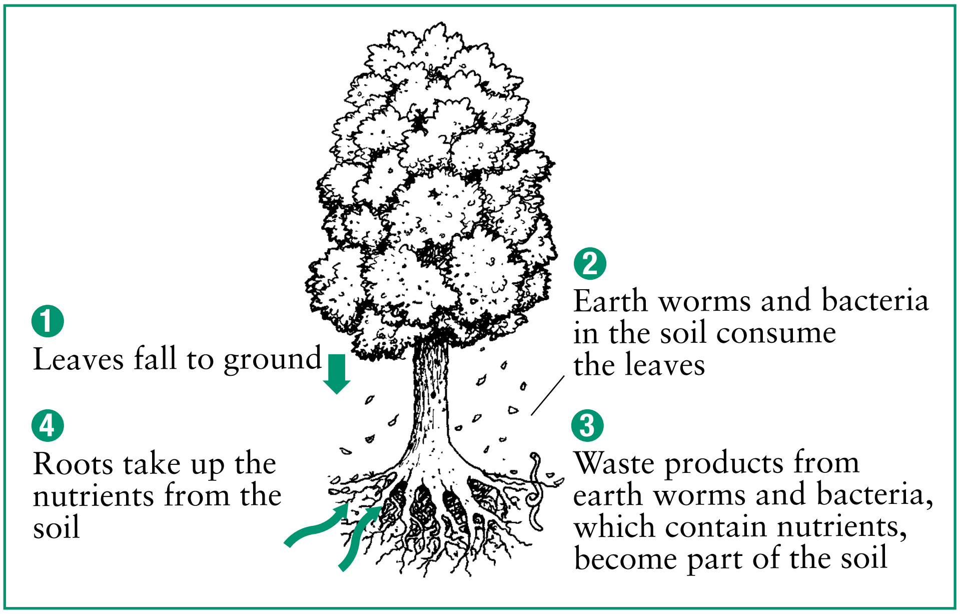


Figure 1. The tree nutrient cycle.

shedding their leaves, trees provide nutrients to the soil, which are made available to the trees once again (Figure 1). In this study, the scientists studied trees growing on Puerto Rico, an island in the Caribbean (Figure 2). The scientists wanted to know if different trees contribute different amounts of nutrients to the soil. By learning if some kinds of trees contribute more nutrients to the soil, the scientists could determine if those kinds of trees should be planted in areas where the soil needs more nutrients. This is especially important in the tropics, where the soil often has fewer nutrients than in other forested areas of the world.

Figure 2. The Caribbean

Reflection Section

- What is one of the problems the scientists were trying to solve?
- Do you think that it would be good to plant trees that contribute more nutrients to the soil? Why or why not?

Methods

Trees contribute nutrients to the soil in many ways. One of the primary ways they do this is by shedding their leaves. When leaves fall to the ground, bacteria, fungi, and animals such as earthworms digest the leaves, moving the nutrients from the leaves to the soil. The scientists decided to collect falling leaves and to *analyze* the leaves for nutrient content. They selected trees that had been planted 23 to 26 years earlier in the Luquillo (lu **ke** o) Experimental Forest in Puerto Rico (Figure 3). Puerto Rico is an island in the Caribbean (See Figure 2 and locate Puerto Rico on the map).

The scientists chose to study 10 types of trees that are usually planted to produce wood products such as lumber, baseball bats, and paper. The scientists randomly (**ran** dum le) selected six trees to study from each species. This means that the selection of trees was purely by chance, like a drawing in a lottery. For each type of tree studied, the scientists hung a wire basket from the selected trees (Figure 4). The baskets caught some of the falling leaves. Every 2 weeks, the leaves were collected, weighed, and a chemical analysis was done to determine the amount of nutrients in the fallen leaves. The scientists collected the leaves 29 times over a period of 58 weeks. How many total baskets of leaves did the scientists analyze? (Multiply 10 tree species X 6 baskets X 29 collections.) Each time, the scientists weighed the leaves to determine the quantity of *biomass*. They analyzed the leaves for the following nutrients: Nitrogen (N), phosphorous (P), potassium (K), calcium (Ca), and magnesium (Mg). The amount of these nutrients measured in the leaves helped the scientists to determine their quality.

Figure 3. Luquillo Experimental Forest.

Reflection Section

- After leaves fall to the ground, decomposers, such as bacteria and fungi, and animals such as earthworms, help to move the nutrients from the leaves to the soil. Do you think that the soil receives the same amount of energy as was in the leaves? Why or why not? (Hint: Think about the laws of energy.)

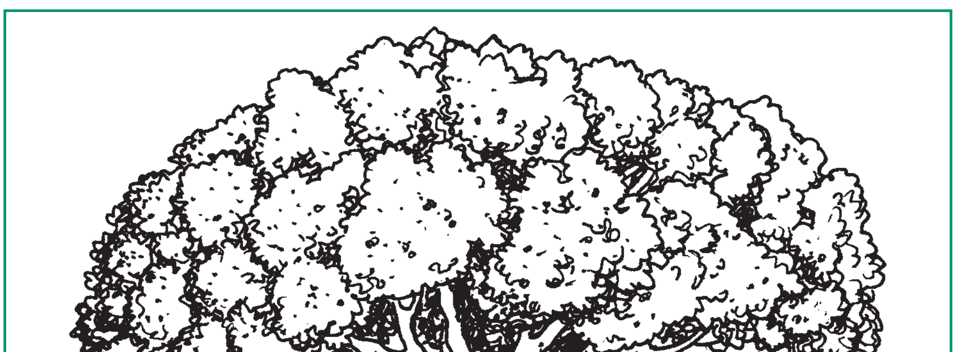


Figure 4. Wire mesh baskets were used to catch falling leaves.

- The scientists collected leaves over the course of a little over 1 year. Why do you think that they wanted to collect leaves during different times of the year?

Results

The scientists found that the 10 species studied differed in both the number of fallen leaves and the quality of the nutrients. They also found that there was a relationship between the number of fallen leaves and the quality of the nutrients. For example, if the nutrient content of individual leaves was low, there usually was a high quantity of biomass, or a lot of fallen leaves. If the nutrient quality of the leaves was high, not as many leaves fell. That meant that the amount of overall nutrients available to the decomposers in the soil was about the same for most tree species (Figure 5).

The scientists also found that before the trees shed their leaves, some of the trees took nutrients back from their leaves before shedding them. Those trees kept much of their nutrients rather than contributing them to the soil through fallen leaves. The scientists concluded that there were three groups of trees. The first group of trees kept their nutrients within the tree itself. The second group cycled most of their nutrients *externally*, meaning that the nutrients were shed with the leaves and cycled into the soil for later use by the tree and

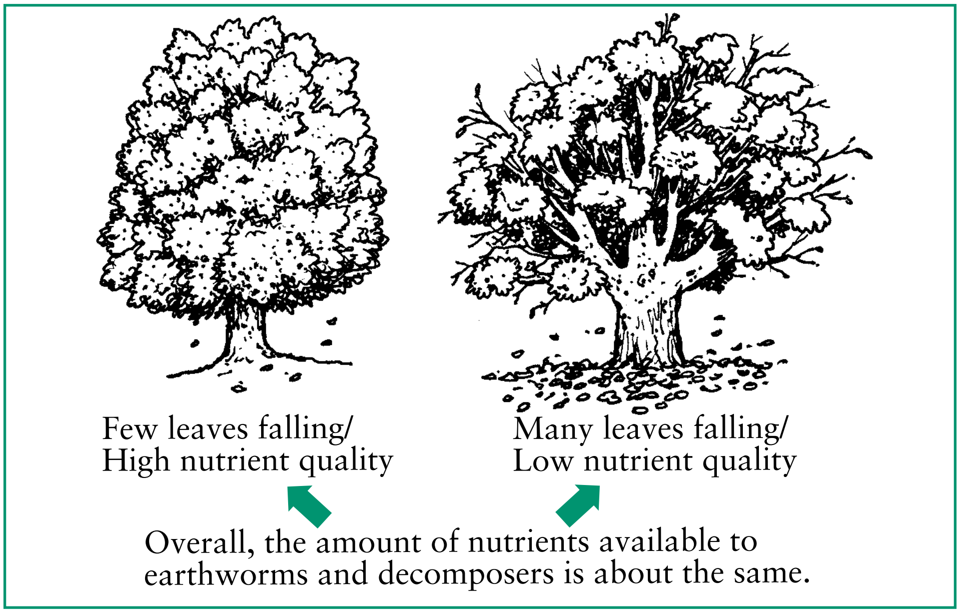


Figure 5. Overall, the amount of nutrients from falling leaves was equal.

other plants. The third group used both kinds of nutrient cycling.

Reflection Section

- Think about all of the animals and plants in the forest. What do you think might be the advantages of external nutrient cycling for other plants and animals? What might be some advantages for the trees when they take the nutrients back from their leaves before shedding them?

- In what ways is energy scattered or spread around during external nutrient cycling?

Implications

Not all trees cycle their nutrients in exactly the same way. If forest *managers* want to enrich soil with a lot of *organic* matter, they should plant trees that shed a lot of leaves. If they want to put a lot of nutrients into the soil quickly, they should plant trees that shed leaves with a high nutrient quality. By knowing the nutrient quality of fallen leaves, forest managers can help nature cycle nutrients from trees to the soil and back to the trees again.

Reflection Section

- In the fall, many people rake the fallen leaves from their yards. What happens to the nutrient cycle when people remove the fallen leaves? How do some people make up for the loss of nutrients available for plant growth? (Hint: What do people usually do in the spring to encourage tree and plant growth?)

- When people build a compost bin, they are providing a special area for leaves and other organic wastes to decompose (Figure 6). What kind of organisms are causing the organic matter to decompose in a compost bin? How is a compost bin like a forest floor? How is it different?

Figure 6. Many people use a compost bin to recycle and reuse their leftover, non-meat foods, fall leaves, and grass clippings. They then use the compost for their gardens and trees.

FACTivity

In this FACTivity, you will explore the bacteria living in the soil near your home or school. The question you will be answering is: What kind of bacteria live in different kinds of soil? It will take 3 to 4 weeks to complete this FACTivity, so be patient. Bacteria need time to grow! You will need:

- 4 clear plastic 2-liter soda bottles with labels removed
- Enough clear, sturdy plastic wrap to cover the bottles
- four rubber bands
- marker
- masking tape
- 2-gallon bucket
- a 1-cup measuring cup
- tablespoon
- paint stirrer or other stirring utensil
- 4 small buckets of soil or mud, each collected from one of four different sources (like a pond, garden, stream, forest, yard, etc.).
- 4 small buckets of water, one from each place you collected the soil (use distilled water for soil collected from a dry place).
- 4 sheets of newspaper
- 1 cup of powdered chalk (crush several pieces of chalk or you can buy some powdered chalk at a hardware store)

Wash your hands before starting. If you have a cut on your hand, wear latex gloves when working with soil. Divide into four groups. Each group will prepare one of the experiments. Be sure to match the bucket of soil with the bucket of water from the same source. Label each bucket with the source of soil or mud and water using the masking tape and marker.

For each experiment:

Cut off the top end of your plastic bottle. The top end will be used as a funnel, and the bottom will hold your experiment. Shred the sheet of newspaper into thin strips and set it aside. In the 2-gallon bucket, add 5 or 6 cups of soil or mud. Pick out all of the sticks, leaves, and pebbles. While stirring, slowly add water (from the same source) until the mixture becomes like a thick cream. Add the shredded newspaper and 1 tablespoon of powdered chalk. Mix gently, and make sure the mixture is wet enough to flow through the funnel. Label your plastic bottle with the source of the soil. Then, using the funnel, pour about 1 centimeter or 1/2 inch of the mixture into the plastic bottle. With one hand over the top of the plastic bottle, gently tap the mixture on a hard surface to allow the mixture to settle evenly. Continue this process until you have filled the bottle to within about 4 centimeters or 2 inches from the top. Cover the top with plastic wrap and seal with the rubber band. Place your bottle in a well-lit place, but not in direct sunlight. Keep it out of heat and at room temperature.

For 3 or 4 weeks, observe the bottles daily. Look for color changes in the mixtures. Record your observations, using the chart below as an example. You may draw, label, and color a picture of each of the jars at the end of each week.

You should begin to see different colors in the bottles. What are the colors and where are they located in the bottle? What do you think causes the different colors?

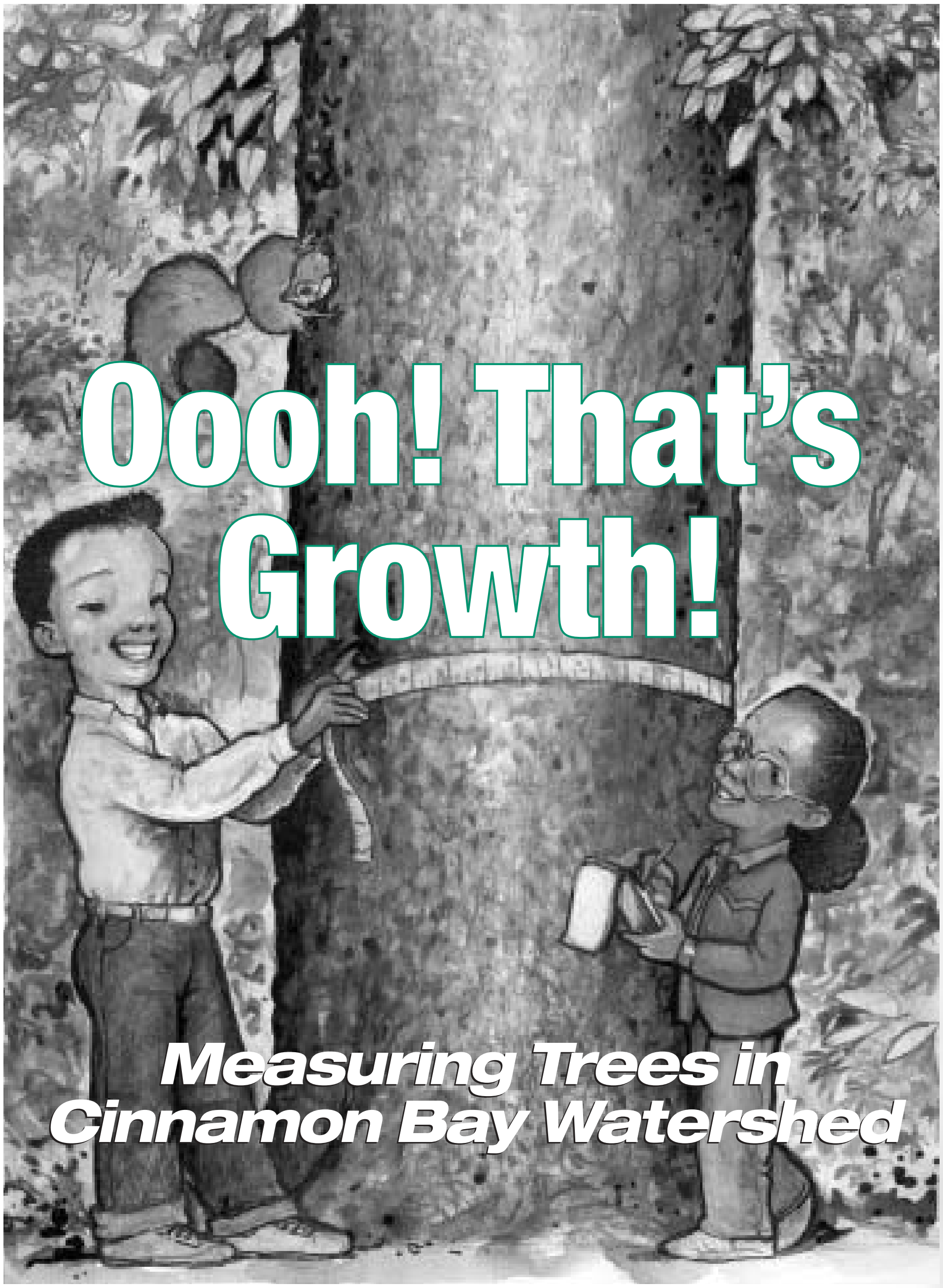
- Red and orange are purple photosynthetic (**fo** to sin **theh** tik) bacteria
- Green at the surface are cyanobacteria (**si** an o bak **ter** e uh) and algae
- Olive green in the middle or lower area are green sulphur bacteria
- Black patches are iron sulfide, a chemical formed by certain bacteria

To learn more about these different kinds of bacteria, visit www.ucmp.berkeley.edu/bacteria/bacteriasy.html

This FACTivity was adapted from an activity titled "Biosphere in a Bottle" developed by the National Association of Biology Teachers. For more fun activities related to bacteria, visit http://www.microbe.org.

From: Cuevas, E. & Lugo, A. E. (1998). Dynamics of organic matter and nutrient return from litterfall in stands of ten tropical tree plantation species. *Forest Ecology and Management*, 112: 263-279.

To learn more about nutrient cycling, visit http://www.swifty.com/apase/charlotte/soil7.html



Oooh! That's Growth!

Measuring Trees in Cinnamon Bay Watershed

Meet Dr. Weaver:

I like being a scientist because I do a little bit of everything. My background has allowed me to travel, work in different cultures, learn new languages, and work with people in developing countries on many practical projects.

Dr. Weaver

Glossary:

watershed (**wä** tür shed): Land area with small streams that deliver water to a larger stream.

represent (rep re **zent**): To be an example of.

diversity (duh **vür** suh te): The quality of being different or varied.

sustainable (suh **stan** uh bul): The quality of surviving or being maintained over a specific time period.

conservation (kän sür **va** shun): The care and protection of natural resources such as forests and water.

sea level (**se lev** ul): The level of the surface of the sea.

elevation (el uh **va** shun): The height above sea level.

topography (tuh **pog** ruh fe): The surface features of a region, such as rivers, hills, and valleys.

diameter (di **am** uh ter): The distance equal to a straight line passing through the center of a circle, cylinder, or sphere.

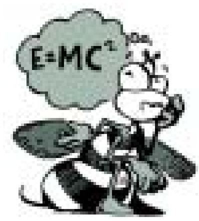
species (**spë** sëz): Groups of organisms that resemble one another in appearance, behavior, chemical processes, and genetic structure.

Pronunciation Guide

a	as in ape	ô	as in for
ä	as in car	u	as in use
e	as in me	ü	as in fur
i	as in ice	oo	as in tool
o	as in go	*ng*	as in sing

Accented syllables are in **bold**.

Thinking About Science



When studying the natural environment, scientists sometimes have to wait many years to discover new things. The scientist in this study wanted to know how the trees were changing in the Cinnamon Bay *watershed*, St. John, U.S. Virgin Islands National Park (Figure 1). He was interested in knowing what kind of new trees were growing and what kind of trees were dying. He also wanted to know how fast the trees were growing. If people want to understand the natural environment, they have to know how to describe it. Usually, the best way to describe an environment is to observe it, and then to record your observations. When you know what an environment looked like one year, you can compare it with other years to tell how much it has changed.

Thinking About the Environment

The Virgin Islands National Park is located in the U.S. Virgin Islands (Figure 1). In 1976, the United Nations Educational, Scientific, and Cultural Organization (UNESCO, u **nes** ko) named the national park a Biosphere (**bi** o sfer) Reserve (re **zerv**). (The United Nations is an international organization that works for world peace and security.) A Biosphere Reserve is a special label given to natural areas around the world that *represent* the world's natural *diversity*. A biosphere reserve should be managed so that it stays healthy into the future. This is called keeping the area *sustainable*. To manage a Biosphere Reserve for sustainability (suh **stan** uh bil uh te), managers have to consider *conservation*, research, education, and whether and how to build structures for human use. All of these things must be balanced so that the area stays healthy into the future.

Figure 1. Location of U.S. Virgin Islands in the Caribbean.

Introduction

In 1718, Danish settlers moved to what is now the U.S. Virgin Islands. They cut down

Thinking About Ecology

All living things grow and develop. Think about yourself and your friends. As a living thing, you grow and develop too. Once you stop growing physically, you will continue to change and develop in other ways. When living systems such as forests stop growing bigger, they continue to develop in other ways. In this study the scientist wanted to know how the trees were growing and developing in a watershed in the Virgin Islands. By learning how the trees were growing and developing, he would know about the mixture of trees in the watershed. With this information, the scientist can help managers make better decisions about how to keep the area healthy and sustainable.

most of the trees and planted sugar cane. By 1750, almost all of the original trees had been cut down. Over time, new trees were planted or began to grow on their own. In 1917 the United States bought the Virgin Islands from Denmark. By then, only about 10 percent of the island was being used for crops, and the rest of it was again a forest. (What percentage was forested? Subtract 10 percent from 100 percent.) In 1956, the United States established a national park on one of the islands. The United Nations named the national park a Biosphere Reserve in 1976. To help manage the park as a Biosphere Reserve, the National Park Service wanted to understand how fast the trees were growing. To do this, they invited the Forest Service to do a study of the trees in the Cinnamon Bay watershed, one of the areas within the Biosphere Reserve (Figures 2 and 3).

Reflection Section

- If you were the scientist, how would you study how well the trees were growing in the Cinnamon Bay watershed?

- Why do you think the United Nations would like areas to be managed sustainably?

Figures 2 and 3. Cinnamon Bay watershed in the U. S. Virgin Islands National Park.

Method

The Cinnamon Bay watershed covers 1.32 km^2 (How many square miles is that? Multiply 1.32 X .621), and rises from *sea level* to 330 meters in *elevation* (How many feet is that? Multiply 330 X 3.28). Because the scientist could not study the entire area by himself, he decided to identify 16 smaller areas within the watershed to study. Because he wanted these areas to represent the whole watershed, he selected areas at different elevations and *topography*. (Figure 4).

How many areas have been identified in Figure 4? Compare this number with the number of areas the scientist studied. You should now realize that there was one more area identified by the scientist that is not shown in Figure 4. The scientist located the 16th area near the highest point of the watershed, at 275 meters in elevation. (How many feet is that?)

The scientist then measured the height and *diameter* of almost every tree in the 16 areas. When scientists measure the diameter of a tree,

Elevation Topography	60 meters (How many feet? Multiply 60 X 3.28)	120 meters (How many feet?)	180 meters (How many feet?)	210 meters (How many feet?)	240 meters (How many feet?)
Mountain Ridge	10 X 50 meters (How many feet?)	10 X 50 meters *For example: This area is on a mountain ridge at an elevation of 120 meters*	10 X 50 meters	10 X 50 meters	10 X 50 meters
Mountain Slope	10 X 50 meters	10 X 50 meters	10 X 50 meters	10 X 50 meters	10 X 50 meters
Valley	10 X 50 meters	10 X 50 meters	10 X 50 meters	10 X 50 meters	10 X 50 meters

Figure 4. Areas studied in the Cinnamon Bay watershed.

they always measure it at 1.37 meters (or 4.5 feet) above the ground. This measurement is called d.b.h., or diameter at breast height (Figure 5). If the d.b.h. of a tree was less than 4.1 centimeters (or 1.61 inches), the scientist did not include it in his observations. For every tree measured, the type of tree was identified and recorded. The scientist then left the area to grow for 5 years. When he returned 5 years later, he counted all of the new trees and the number of trees that had died, and measured how much the living trees had grown.

Reflection Section

- Why do you think the scientist studied areas at different elevations?

Figure 5. Research assistant measuring d.b.h. in the Cinnamon Bay watershed.

- Why do you think that scientists always measure trees at d.b.h.? (Hint: What if one scientist measured a tree's diameter at 3 meters high and another scientist measured the same tree's diameter at 4 meters? Would their measurements be the same?)
- What three kinds of information did the scientist have after he took his measurements 5 years later?

Results

After 5 years, the scientist counted 206 new trees in the 16 areas. He also found that 161 trees had died. Overall, would you say that the watershed is gaining trees or losing trees? Why? The trees grew an average of 0.07 centimeters a year when measured at d.b.h. Most of the trees grew < (less than) 0.10 centimeters a year in height (How many inches is that? Multiply 0.10 X .394) The scientist found no new tree *species* growing in the study areas.

Reflection Section

- Think about the trees where you live. In the spring, new growth appears as new stems and leaves. Compared to the trees where you live, would you say that the trees in Cinnamon Bay watershed were growing faster or slower?

- Based on the results of this research, do you think the watershed is becoming more diverse in its tree species? Why or why not?

Implications

This study will help forest managers in many ways. First, it tells them how much time will be needed for the forest to grow back if, in the future, the trees are cut down or a hurricane destroys the forest. Second, it tells scientists what kind of trees grow at different elevations in this tropical watershed. This could be especially helpful if managers want to plant trees in a similar area. Finally, this study helps managers to identify which trees are common and which are rare in the tropical watershed. It also tells managers which trees will grow to maturity, if there is no hurricane or other disturbance. You can see that by studying the current conditions of a natural area, scientists can help forest managers protect the area into the future.

Reflection Section

- Remember that the Cinnamon Bay watershed is part of the Biosphere Reserve. Go back to "Thinking About the Environment" and look at what must be balanced in a Biosphere Reserve. Which one of those four things are reported on in this article?

- Do you think the scientist should go back to Cinnamon Bay watershed in 5 more years and take more measurements? Why or why not?

FACTivity

For this FACTivity, you will answer the question: What is the relationship between tree height and d.b.h.? In other words, when trees get taller, does the d.b.h. get smaller, larger, or stay the same? You might be able to guess at the answer to this question based on your existing knowledge. What do you think the relationship is? Your guess is a hypothesis (hi̲ **paw** thuh sis). A hypothesis is an assumption that is made for the time being, so that it can be tested using planned and recorded observation. For this FACTivity, you will need a cloth (flexible) tape measure.

The method you will use to test your hypothesis is this: Go to an area that has trees of varying heights. You will first place the trees into categories, based on their height. Since you will not be able to measure the height of most of the trees, for this FACTivity you will be placing the trees in general categories. Find at least three trees in each of these categories:

- Short trees (those that are not much taller than a human)
- Medium height trees (those that are much taller than a human, but not taller than a two story-building
- Tall trees (those that are taller than a two story building

If you cannot find enough trees in these categories near your school, you may want to have your classmates take measurements of trees at home or in different places. The more trees you can measure in each of these categories, the more information you will have to answer the question.

To measure each tree's diameter at d.b.h., place the tape measure at ground level. Measure up the tree's trunk to 1.37 meters (4.5 feet). Have your classmate hold a finger at that height on the trunk. At that height, measure the circumference of the tree. The circumference is the distance around the tree trunk. For each measurement, you will have to calculate the diameter from the circumference. To do this, multiply the circumference by .3183. No matter how large the circumference, the diameter is always .3183 times the size of the circumference. Record all of your measurements. You can use the chart on the right as an example. After you have finished recording all of your measurements, you will need to determine if there is a relationship between tree d.b.h. and tree height.

To determine if there is a relationship between tree height and d.b.h., create a histogram (bar chart) from your recorded information. You can use the sample on the right to create your bar chart. See an example of a bar chart below the sample.

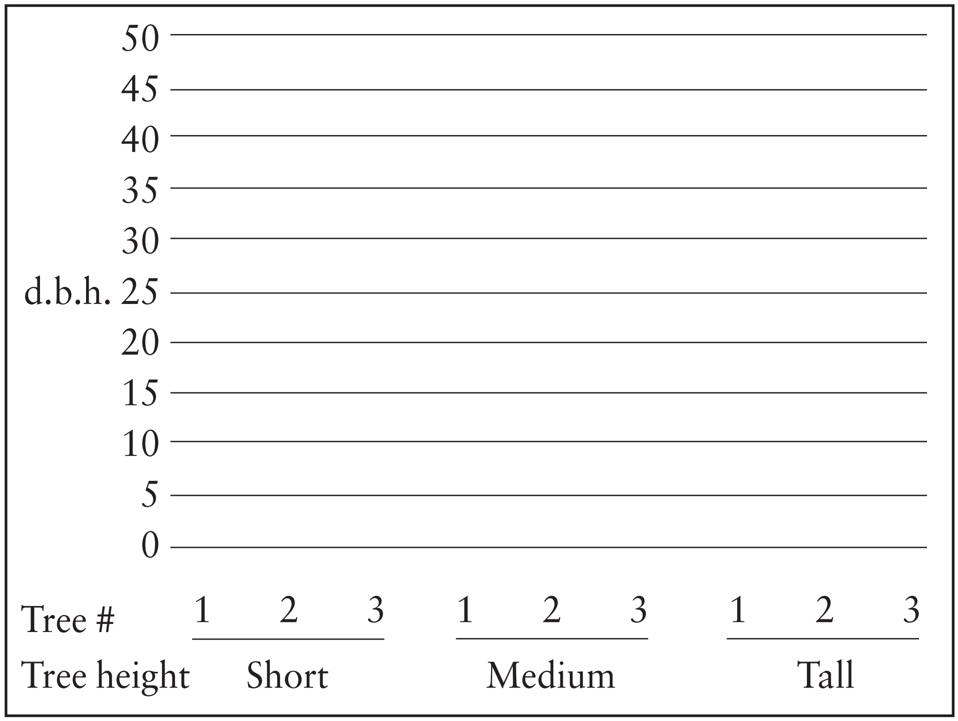
After you have made your bar chart, can you see a pattern in the d.b.h. of the trees? What is the pattern? The pattern is a relationship that you have discovered between tree height and d.b.h. Now that you know this, what is the answer to the question asked at the beginning of this FACTivity? Was your hypothesis correct?

From Weaver, P. L. (1990). Tree diameter growth rates in Cinnamon Bay watershed, St. John, U.S. Virgin Islands. *Caribbean Journal of Science*, 26(1-2): 1-6.

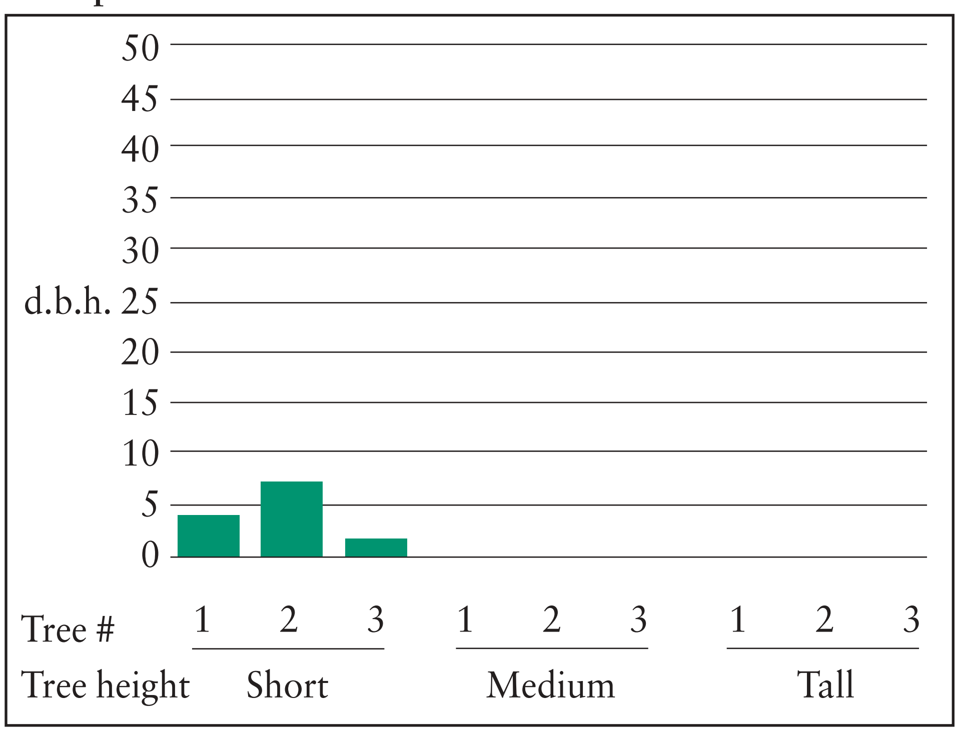
Sample chart for recording measurements

	Short trees	Medium trees	Tall trees
Tree #1 – d.b.h.			
Tree #2 – d.b.h.			
Tree #3 – d.b.h.			

Sample bar chart



Example of a bar chart



It's a Gas!

The Exchange of Gases Between the Soil and the Atmosphere

Meet Dr. Keller *(with hat)*:

I like being a scientist because I get to follow my natural curiosity to learn how the Earth system works. My work is split between the field, the office, and the laboratory and I have a great deal of independence. I love to learn new things.

Dr. Keller

Thinking About Science

Chemistry is the science of the building blocks of all matter. Atoms are the most basic building block. Molecules are combinations of two or more atoms of the same chemical element. All matter is built from over 100 chemical elements. Examples of elements are nitrogen, hydrogen, oxygen, and carbon. Compounds are made up of two or more elements. To make it easier to

Glossary:

gaseous (**gash** us): In the form of gas.

greenhouse effect (**gren** howls e **fekt**): Warming of the Earth's surface that occurs when the sun's heat is trapped by the atmosphere.

climate (**kli** met): The average condition of the weather at a place.

bacteria (bak **ter** e uh): Living things that only have one cell and can only be seen using a microscope.

specialization (**spesh** ul i **za** shun): Special study of something or working only in a special topic or area.

compact (käm **pakt**): To pack closely and firmly together.

porous (**poor** us): Full of pores or tiny holes through which water, air, etc., may pass.

sample (**sam** pool): A part or piece that shows what the whole group or thing is like.

anaerobic (**an** ä **ro** bik): Existing in the absence of oxygen.

Pronunciation Guide

a	as in ape	ô	as in for
ä	as in car	u	as in use
e	as in me	ü	as in fur
i	as in ice	oo	as in tool
o	as in go	*ng*	as in sing

Accented syllables are in **bold**.

imagine, think about the alphabet. Atoms are like different letters. There could be "A" atoms, "B" atoms, and "C" atoms, for example. Elements are like a single letter, such as A, I, or T. Molecules are like strings of the same letter (or element), such as BBB or MMMM. Compounds are like words, which are made from different letters (or elements). When elements interact and become compounds, their structure changes. Elements can form an almost limitless number of compounds, just as letters can form an almost limitless number of words. These compounds can be solid, liquid, or gas. Some scientists study the structure and behavior of *gaseous* compounds. In this study, the scientists were interested in studying the gaseous compounds that go into the atmosphere as greenhouse gases.

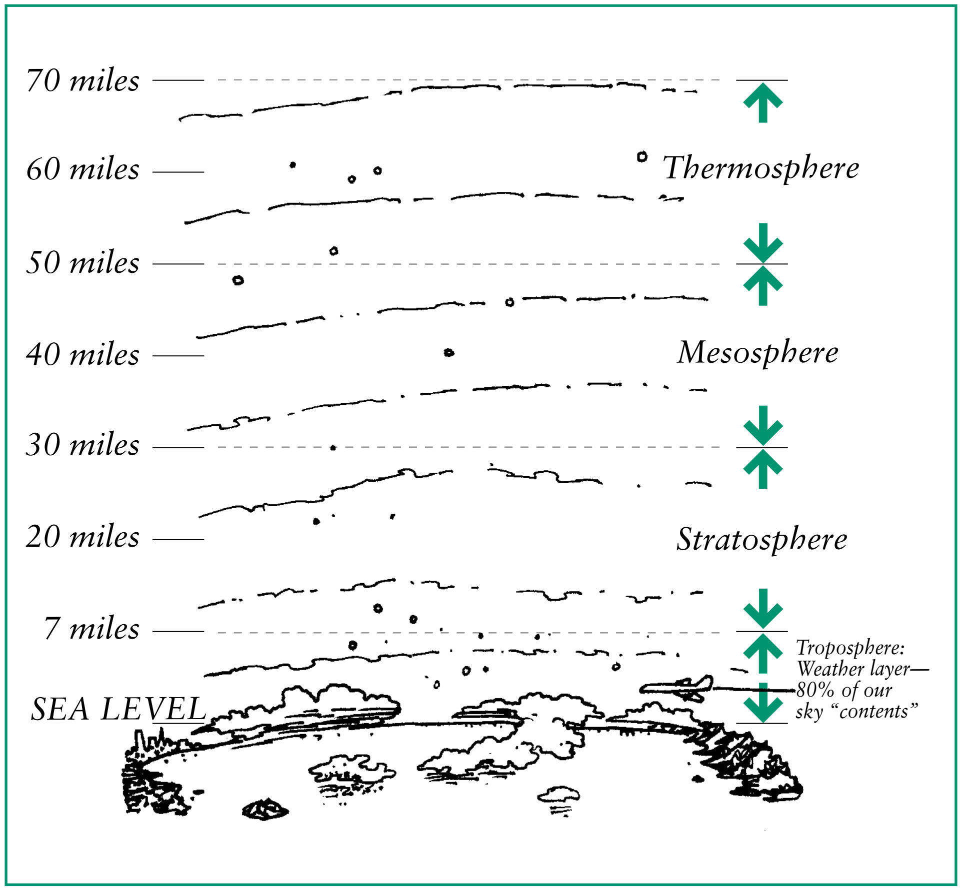


Figure 1. The Earth's atmosphere. The troposphere is the section of our atmosphere reaching from sea level up to 7 miles. Most clouds are contained within the troposphere. When you fly somewhere in a jet, you are flying through the middle and upper portions of our troposphere.

Thinking About the Environment

The *greenhouse effect* is caused by certain gases that act like glass in a greenhouse. They reflect heat in the atmosphere back down to earth (Figure 1). The amount of heat trapped in the atmosphere can vary, depending on the type of gas and how long it stays in the atmosphere. The major greenhouse gases are water vapor, carbon dioxide (**kär** bun di **ox** id), methane (**meth** an), nitrous (**ni** trus) oxide, and chlorofluorocarbons (**klôr** o **flôr** o **kär** buns), also called CFCs. We need a certain level of greenhouse gases to maintain a liveable *climate* on Earth. If we had too small an amount of greenhouse gases, the Earth's climate would get too cold. If we get too great an amount of greenhouse gases, the Earth's climate will get too warm. Human activities, such as burning fossil fuels like petroleum, can create greenhouse gases. The scientists in this study looked at greenhouse gases from another perspective. They looked at how human activities have enabled soil *bacteria* to increase the amount of nitrous oxide in the atmosphere.

Introduction

Tropical forests are sometimes cut down so that humans can use the trees for wood and other products. Then, the cleared land is made into a pasture so that cattle can be raised for human consumption. When forest land becomes pasture, the soil changes. It becomes more *compacted* and less *porous*. (Can you think of why this might happen? Think about the size and weight of cattle.) Previous research had shown

Thinking About Ecology

Often, scientists study one particular event or object. While such *specialization* helps scientists to understand a lot about that one event or object, it does not always help them to understand how that event or object relates to other events or objects. Ecologists (e käl uh jists) are scientists who study how living things relate to each other and to nonliving things. In this study, the ecologists were studying the nitrogen cycle (Figure 2). The nitrogen cycle explains the relationship of the element nitrogen with other elements, and with plants, animals, and bacteria. Bacteria are important in the cycle, because they convert nitrogen from the atmosphere into forms that plants can use such as nitrates and ammonia. These compounds are used by plants to make other compounds such as protein. Animals who eat plants can use the protein from the plants. Bacteria living in soil convert animal wastes and dead material from plants back into nitrogen compounds. The nitrogen is released back to the atmosphere, and the cycle begins again. This is an example of how life depends on relationships between living and nonliving things. What are some examples of how your life depends on living and nonliving things?

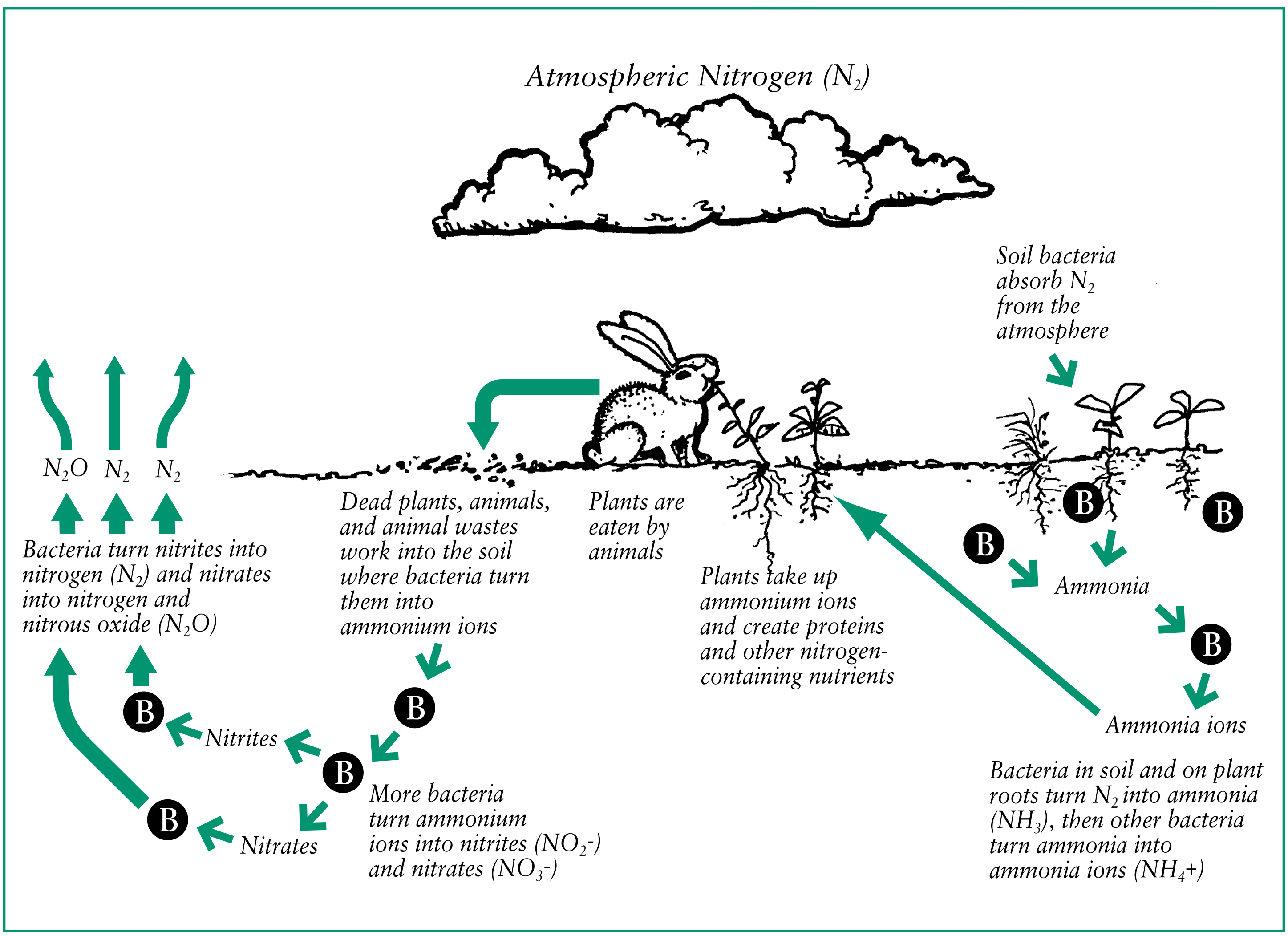


Figure 2. The nitrogen cycle.

that pasture soils release more greenhouse gases than forested land. Sometimes pastures are abandoned after a while. This is often because the soil can no longer produce enough plants to support the cattle. When pastures are abandoned, the forest begins to grow again. No one knew whether soils from these young forests would begin to release less greenhouse gases as the forest grew again. That is the question the scientists wanted to answer.

Reflection Section

- What is the question the scientists wanted to answer? What is the bigger problem their research might help to solve?

- Do you think the scientists needed to visit and study young tropical forests, or could they do all of their research inside a laboratory? Why or why not?

Method

The scientists selected four types of areas to study. They studied old tropical forests, young tropical forests, pastures that were currently being used for raising cattle, and recently abandoned pastures (Figures 3-5). They selected three different areas of each type to study as examples. (How many total areas did they study? Multiply 4 types of areas times 3 examples each.) Then, they picked eight spots in each area where they measured the amount of nitrous oxide (N_2O) in the

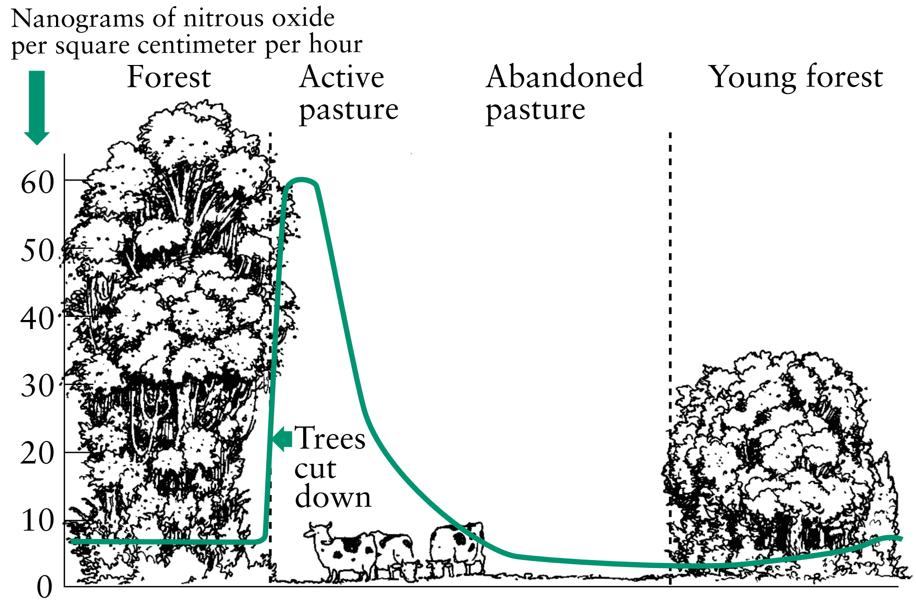
Figures 3-5. An old tropical forest, a current pasture, and a young tropical forest.

soil. (How many total spots did they measure? Multiply 12 X 8.) The scientists measured the amount of nitrous oxide at the top level of the soil at each spot once a month for 12 months. (How many total measurements did they collect? Multiply 12 X 8 X 12. How many measurements did they collect for each type of area? Divide the total measurements by the number of types.) The scientists collected *samples* of the gases that were in the soil by placing an instrument 2 centimeters into the soil (Figure 6). (To find out how many inches that is, multiply 2 X .393.) They took the gaseous samples back to a laboratory. There they measured now much nitrous oxide was in the samples collected from the top level of the soil.

Reflection Section

• Why do you think the scientists studied all four types of areas, instead of just studying young tropical forests?

Figure 6. Photograph of equipment used to collect nitrous oxide gas.



A nanogram is one-billionth of a gram. That's not very much weight! If you took a frito (Fritos® brand corn chip) and smashed it into 1 billion pieces, each piece would weight about one nanogram. At the rate of 60 nanograms per hour, about 60 grams of nitrous oxide would be released in an area 1 kilometer (.621 miles) square. In 1 day, 1,440 grams of nitrous oxide would be released in that square kilometer. How many grams would be released in a month? Although a nanogram is not much weight, you can see that over time, nanograms of nitrous oxide can add up!

Figure 7. The amount of nitrous oxide found in the top layer of the soil over the period of 1 hour in four types of tropical land.

- Do you think that the scientists found that more, the same, or less nitrous oxide was in the soil of young tropical forests compared with the soil in the pasture being used by cattle? Why?

Results

The scientists discovered that the amount of nitrous oxide near the top of the soil was different in the four types of areas (Figure 7). The amount of nitrous oxide is low in old tropical forests. When forests are cleared and used for pasture, the amount of nitrous oxide near the soil's surface rises. As pastures are abandoned and young forests begin to grow, the amount of nitrous oxide at the surface drops to levels even below the old forest levels. The scientists think that water is the key to understanding this pattern. Because cattle hooves compact the soil, pasture land is less able to absorb and drain water. This condition encourages *anaerobic* bacterial activity on plant and animal wastes near the soil's surface. This results in an increased amount of nitrous oxide near the soil's surface, which is then released into the atmosphere.

Reflection Section

- What are two things happening in tropical pastures that might be increasing the amount of nitrous oxide being released into the atmosphere?

- The scientists measured the amount of nitrous oxide 2 centimeters below the surface of the soil. Do you think that same amount of nitrous oxide is being released into the atmosphere? Why or why not?

Implications

The scientists discovered that nitrous oxide is being released into the atmosphere as a part of the nitrogen cycle. They do not know, however, what causes bacteria to turn some ammonium ions into nitrous oxide and others into nitrogen. Nitrogen is a necessary gas in the atmosphere, but nitrous oxide is a greenhouse gas that could cause harm in great amounts. There is still a lot to learn about tropical soils and greenhouse gases. This research shows that humans impact the Earth in ways that we may not be able to see. By making decisions to manage land in different ways, we affect what happens now and what will happen in the future.

Reflection Section

- What other things do you know about the effect of greenhouse gases?

- Do you think that no matter where they are on the planet, pastures cause more nitrous oxide to be released than would happen if the land were a forest? Why or why not?

Discovery FACTivity

In this FACTivity, you will answer the question: What are the similarities between a glass jar with soil and the Earth's atmosphere? The method you will use to answer this question is this: Get two thermometers, a large clear glass jar with a lid (be careful!), and 1 cup of dark soil. Put the soil into the glass jar to a depth of about 4 centimeters (or about 2 inches). Put a thermometer upside down in the jar, and close the lid. Turn the glass jar over, so that the soil is at the lid and the thermometer is right side up. Place the jar in the sunlight or under a high-intensity bulb for 1 hour. Place the second thermometer near the jar.

At the end of the hour, record the temperature outside of the jar using the second thermometer. Record the temperature of the air inside of the glass jar. Compare the two temperatures. Then consider the following questions:

- What part of Earth does the air inside of the jar represent?
- What part of the Earth does the glass represent?
- What part of the Earth does the black dirt represent?

You will see that the soil is heated by the light, which then radiates the heat back into the air where it is trapped by the glass. You have created a greenhouse effect! Now see if you can answer the question posed at the beginning of this FACTivity.

This FACTivity was adapted from Rodriguez, N., Kampen, A., and Dufresne, M. (2000). It's your planet: A study of global warming. An interdisciplinary curriculum designed for middle school students and their exploration of global warming. Visit this Web site for more information and activities: http://www.classtech2000.com/archno2/SessionB/Jesuit/gwarming.htm

From Keller, M. & Reiners, W. A. (1994). Soil-atmosphere exchange of nitrous oxide, nitric oxide, and methane under secondary succession of pasture to forest in the Atlantic lowlands of Costa Rica. *Global biogeochemical cycles*, 8(4): 399-409.

Please Join Us for Dinner:

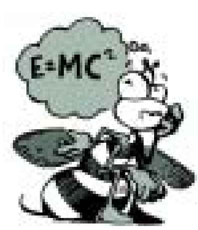
Tropical Birds and Their Temporary Guests

Meet Dr. Latta

(Second from left):

I like being a scientist because of the adventure of working in wild places and the challenge of trying to understand the *ecology* of birds. I think it is important to protect the *diversity* of living things on the planet.

Dr. Latta



Thinking About Science

When scientists observe what happens in nature, they often must create categories for things that they observe. Categories help them to *classify* their observations. Classifying is a way of grouping similar things together. This helps scientists

Glossary:

ecology (e **kä** luh je): The study of the interactions of living things with one another and with their environment.

diversity (duh **vür** suh te): The quality of being different or varied.

classify (**klas** uh fi): To arrange by putting into groups according to some system.

analyze (**an** uh liz): To study or examine carefully.

summarize (**sum** uh riz): To make a summary or a brief report.

forage (**for** ij): Food for animals usually taken by browsing or grazing; the act of taking such food.

adapt (uh **dapt**): To change so as to fit new conditions.

mature (muh **toor**): Fully developed or fully grown.

species (**spe** sez): Groups of organisms that resemble one another in appearance, behavior, chemical processes, and genetic structure.

tropical (**träp** i käl): Of, in, or like the tropics. The tropics is the region of the Earth near the Equator.

understory (**un** der stôr e): Vegetation in a forest that is near the ground.

migratory (**mi** gruh tôr e): Having a characteristic of moving from one place to another.

perch (purch): A tree branch that a bird sits on.

population (päp yoo **la** shun): The whole number of individuals of the same type occupying an area.

Pronunciation Guide

a	as in ape	ô	as in for
ä	as in car	u	as in use
e	as in me	ü	as in fur
i	as in ice	oo	as in tool
o	as in go	*ng*	as in sing

Accented syllables are in **bold**.

analyze and *summarize* what they discover. In this study, the scientists wanted to understand the *foraging* behavior of birds in the Dominican Republic, which is part of an island in the Caribbean (kä **rib** e un) Sea (Figure 1). By analyzing and summarizing their observations of bird behavior, the scientists hoped to better understand how different birds find food.

Thinking About the Environment

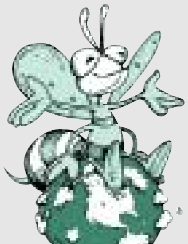
Even the same kind of animals might eat different kinds of foods. Over hundreds or thousands of years, animals have *adapted* to different environments where food is available. In this study, the scientists wanted to study the diets of birds. For example, some birds eat insects, some eat berries, some eat nectar (the sweet liquid from a plant), and some eat seeds. Some birds eat more than one type of food. When different kinds of birds eat different kinds of foods, they can live in the same area because they do not have to compete for the same food source. The same thing is true for other kinds of animals. Because of this, many different kinds of animals can live in the same area.

Figure 1. Location of the Dominican Republic in the Caribbean Sea.

Introduction

Pine forests are common in the *tropical* Caribbean. Usually, these pine forests also have an *understory* of broad-leafed trees. Broad-leafed trees are trees with flat leaves. The pine forests are the home of many different kinds of birds. Although scientists had studied the birds living in other kinds of forests, they had not studied the birds living in tropical pine forests. Some birds live in the pine forests all year. These birds are called residents (Figure 2). Other birds are *migratory*, living in

Thinking About Ecology



Diversity is an important quality for all *mature* communities of life. In a mature natural environment, it is important to have a diversity of *species*. This means that natural communities usually have different kinds of animal and plant species. It is also important for differences to occur in the same kinds of animals and plants. Think about the community that you live in. Your family is different in many ways than other families in your neighborhood, and you are different in many ways from other people. In the natural world, there is a diversity of other animals and plants. In this study, the scientists were interested in observing how different birds eat different foods. When there is a diversity of animals living in an area, there is food available for all of the animals.

Figure 2. Research assistant with resident bird.

the pine forests only during the winter months. Migratory birds fly from the colder north to spend the winter in the tropics, where it is warm. The scientists in this study wanted to learn what kind of food the resident birds and migratory birds eat during the winter months.

Reflection Section

- If you were the scientist, how would you study what birds eat in the pine forests?
- Do you think that different birds eat different kinds of foods in pine forests? Why or why not?

Methods

First, the scientists selected 12 areas in a large pine forest. These areas had trees that were typical of the trees in the larger pine forest surrounding the 12 areas. After they selected an area, they drew an imaginary circle 16 meters in diameter (To find out how many yards this is, multiply 16 by 1.09). Then they identified the type of trees within the circles. The scientists observed the foraging behavior of birds by walking through different sections of the pine forest each day. They recorded the type of bird and the bird behavior they observed. To record how each bird was getting its food, the scientists classified the birds' foraging behavior into five types (Table 1). They also recorded four more things: 1) the species of bird, 2) whether the bird species was a resident or a migrant, 3) whether the bird was in the pines, in the broad leaf area, or in the overlap of the two areas when it was getting its food, and 4) how each bird was getting its food (Table 2 and Figure 3).

Type of foraging behavior	Description of foraging behavior
Glean (glen)	The bird remained on a perch and picked a food item from another surface
Jump	The bird jumped from a perch or any surface to get a food item
Probe	The bird poked or pecked into a surface to get a food item from below the surface
Sally-Air	The bird, while in the air, captured its food item from the air
Sally-Surface	The bird, while in the air, captured its food item from a surface

Table 1. Classifications of how birds captured their food.

Species of bird	Migrant (M) or Resident (R)	Seen in broadleafed area most of the time?	Seen in the mixed broadleaf/ pine area most of the time?	Seen in the pine area most of the time?	Most often used foraging behavior
Ground warbler	R	Yes	No	No	Glean
Palm warbler	M	No	Yes	No	Glean
Broad-billed Tody	R	No	Yes	No	Sally-Surface

Table 2. Example of how the scientists summarized their observations.

Reflection Section

- Why do you think the scientists selected smaller areas to identify trees instead of the whole pine forest?

- How do you think the scientists knew that the trees in the 12 areas were similar to the trees in the larger pine forest?

Results

Seventy-eight percent of the birds foraged in an area between 5 and 10 meters from the ground (How many yards is this? See the "Methods" section above to find out how to calculate this). This is the height where the pine needles and the broad leaves overlap. Below 5 meters high and closer to the ground, the plants are mostly broad leafed. Above 10 meters, the plants are mostly pine trees. Most of the birds they observed in the Caribbean pine forests were residents and lived there all of the time. The rest were migratory (Figure 4). Almost half of all birds ate insects, and the rest ate other kinds of foods (Figure 5).

Even though most of the birds ate insects, the scientists found that the birds used a lot of different foraging behaviors to capture insects. For example, birds gleaned (or picked) insects from leaf surfaces, they caught insects while flying in the air, and they picked insects from surfaces while they were flying. Not only did the birds use different behaviors to capture insects, they usually captured insects from different surfaces or areas. The scientists found that the pine forest, with its broad-leafed understory, provided a variety of food for many different kinds of birds.

Figure 3. Forest with understory and broadleaf/pine overlap.

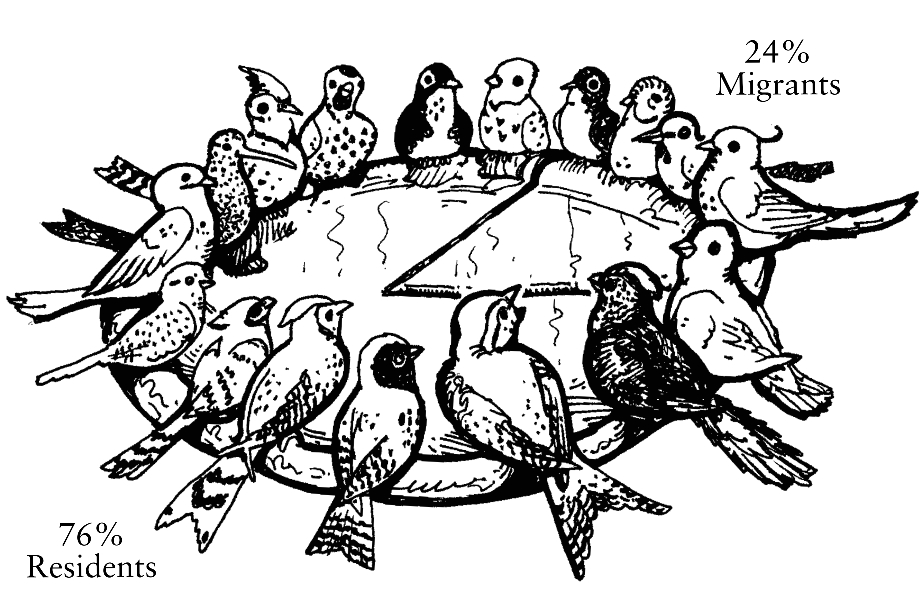


Figure 4. Percentage of permanent and migratory birds.

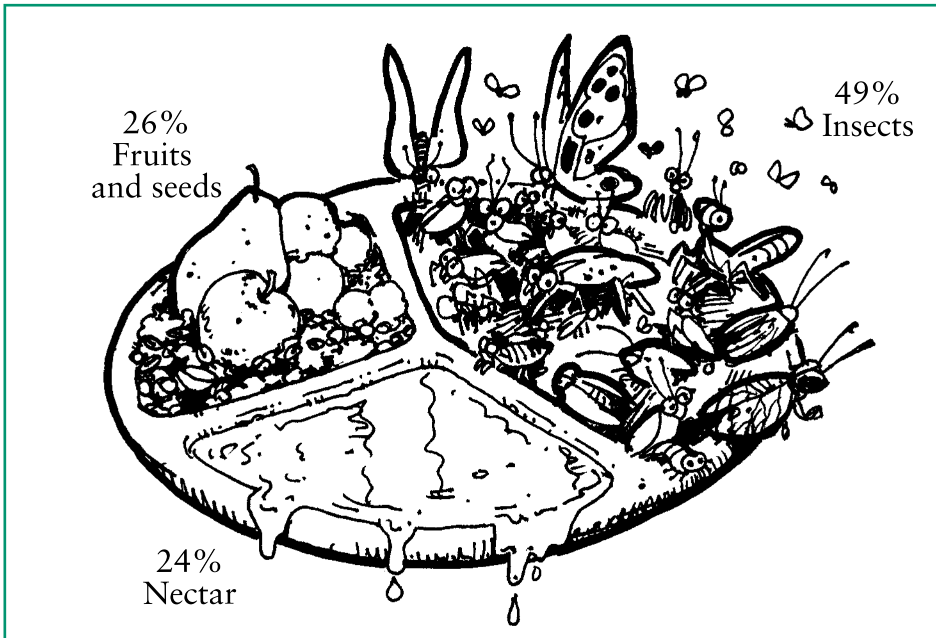


Figure 5. Food sources of birds in the Caribbean pine forest.

Reflection Section

- Name two examples of diversity described in this article. Think about the type of birds, the foods they eat, how they get their food, and the trees and plants where they find food.
- In what ways did diversity help the birds?

Implications

Throughout North America, the number of songbird species is declining. Many of those songbirds are migrants that live in the tropics during the winter. This study shows how migrant and resident birds can live in the same place at one time. With this information, people can make sure that resident and migrant birds have the kinds of places in the tropics that they need to survive. By providing and protecting the forests that different kinds of birds need, people can help reduce the declining numbers of songbirds in the future.

Reflection Section

- A healthy food web is balanced between food sources and the animals that eat the food. Think about insect-eating birds. What would happen to the population of insects if the birds were not there to eat the insects?

- How might protecting some tropical forests help reduce the declining number of songbirds in North America?

FACTivity

The scientists found that birds ate three kinds of foods. These foods were 1) insects, 2) fruits and seeds, and 3) nectar. They also found that birds captured their food in the air, and they gleaned, jumped, and probed for their food (See Table 1). In this FACTivity, you will answer the question: What kinds of physical characteristics might different birds have to help them capture their food? Here is the method that you will use to explore the question: You will need five large pieces of plain white paper and crayons. On each piece of paper, design a bird that captures and eats different kinds of foods. Pay careful attention to the kind of beak, wings, body shape, and legs the bird should have. You may want to design your birds in small groups, discussing how each part of the bird would help it capture the right kind of food.

Design a—

- Bird that gleans and eats seeds and fruit
- Bird that probes into flowers and eats nectar
- Bird that captures insects while flying
- Bird that captures insects by probing into trees
- Bird that jumps along the ground and picks insects off of the ground

After designing your birds, you may want to do some research on different birds to learn about the shape of their beaks, the size of their wings, the shape of their body, and the length of their legs. You can explore different birds by using a bird identification book. Compare what you have learned with your own bird designs. What kind of physical characteristics do birds need to capture different kinds of food?

From Latta, S. C. and Wunderle, J. M. Jr. (1998). The assemblage of birds foraging in native West Indian pine (Pinus occidentalis) forests of the Dominican Republic during the nonbreeding season. *Biotropica* 30(4): 645-656.

Another resource: Bird Beak Buffet: http://saveourlake.org/lessons/chpt2/act5.htm.

Some Things Will Always Change:

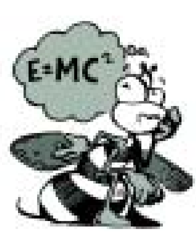
Land Use in a Dry Tropical Forest

Meet Dr. Lugo:

I like being a scientist because it brings me into contact with people who, like me, are fascinated by the *complexity* of nature and have an opportunity to try to figure it out. Then we can put the information to work for the benefit of people.

Dr. Lugo

Thinking About Science



Scientists observe natural areas using many different techniques. One way to observe natural areas is through photographs. In this article, the scientists wanted to learn about changes in

Glossary:

complexity (käm **plek** suh te): The state of being complicated or having many related parts.

latitude (**lat** uh tood): Distance north or south of the Equator.

diverse (di **vürs**): Differing from one another.

biome (**bi** om): An area of Earth with similar plants and animals because of its climate.

climate (**kli** met): The average condition of the weather at a place.

adapt (uh **dapt**): To change so as to fit new conditions.

dense (dens): Having its parts close together.

land use history (land us **hist** ür e): The story of how land has been used by people over time.

barren (**bear** en): Not producing crops, fruit, or many trees.

former (**fôr** mer): Earlier or in the past.

native (**na** tiv): Naturally occurring in an area.

habitat (**ha** ba tat): Environment where a plant or animal naturally grows and lives.

consensus (kän **sen** sus): Agreement of all or most.

Pronunciation Guide

a	as in ape	ô	as in for
ä	as in car	u	as in use
e	as in me	ü	as in fur
i	as in ice	oo	as in tool
o	as in go	*ng*	as in sing

Accented syllables are in **bold**.

an area of land over a long period of time. They wanted to know if trees were growing or had been cut down, or if roads or buildings had been built over the years. To do this, they used photographs of an area taken between 1936 and 1989. The photographs were taken from an airplane. Photographs taken from an airplane are called aerial (**air** e ul) photographs. The aerial photographs were compared with each other to show changes in how the land was being used. By comparing these photographs, the scientists were able to see the changes that had occurred on the land over a long period of time.

Thinking About the Environment

Tropical forests are very diverse. Although most people know about tropical rain forests, they may not know about tropical dry forests. Can you guess what makes dry forests different than rain forests? A rain forest receives more rain than a dry forest (Figure 1). A rain forest can get up to 400 inches or 1,000 centimeters of rain each year (What is the average number of inches or centimeters possible every week? What is the average number possible every day?). A dry forest receives about 20 inches or 50 centimeters of

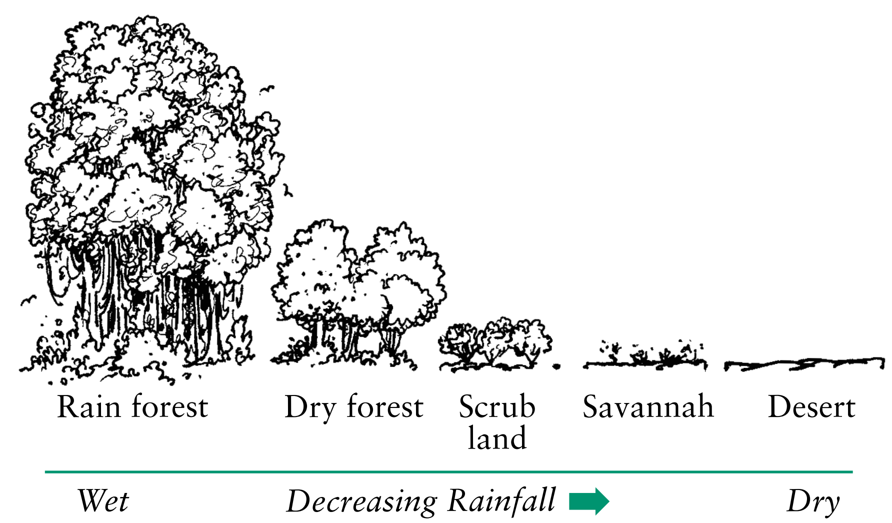


Figure 1. The type and amount of vegetation in the tropics is dependent upon the amount of rainfall received. The amount of rainfall also affects the type of vegetation growing at any latitude.

Thinking About Ecology

Think about the natural area that surrounds your community. Is it a forest, a prairie or grassland, or a desert? The Earth's surface is *diverse*. Besides having forests, grasslands, and deserts, there are also different types of forests, grasslands, and deserts! Have you ever thought about what determines these different types of *biomes* across the Earth's surface? The answer is that areas of the Earth have different *climates*. The climate of an area is determined mainly by its average temperature and average amount of rainfall. The amount of rainfall is the most important factor limiting plant growth in an area. The plants growing in drier areas are *adapted* to lower rainfall. Drier areas often have fewer plants, and the plants do not grow as *densely* as plants in areas with a lot of rain. In this study, the scientists studied a dry tropical forest. The dry tropical forest is the result of the rain shadow effect (Figure 2). Over thousands of years, this forest has adapted to its dry conditions. Although it is still a forest, its trees are shorter and their leaves are not as large as trees in the nearby rain forest (Figure 3).

rain each year (What is the average number of inches or centimeters possible every week?). For this reason, the types of plants and animals living in dry forests are different from those living in rain forests. Trees and animals that are adapted to drier conditions live in tropical dry forests. In this article, you will learn about a dry forest in Puerto Rico. (Just for fun – What is the average amount of rainfall your town or area receives each year?)

Introduction

Guanica (**gwa** ne kä) Forest is a tropical dry forest in the southwest corner of Puerto Rico (Figure 4). In 1981, the United Nations recognized it for being one of the best examples of a dry tropical forest. Before 1919, Guanica Forest was used for agriculture and other human activities. In 1919, Guanica Forest became legally protected from most human development. Since 1919, more acres have been added to Guanica Forest. Land that had been used in the past for human activities is now inside the forest boundaries. It is mostly protected from development inside the boundaries. The land in and around Guanica Forest has been changing. The scientists in this study wanted to know how Guanica Forest and the land around it has changed over the years. For example, they wanted to know whether the trees have been growing back where crops used to be.

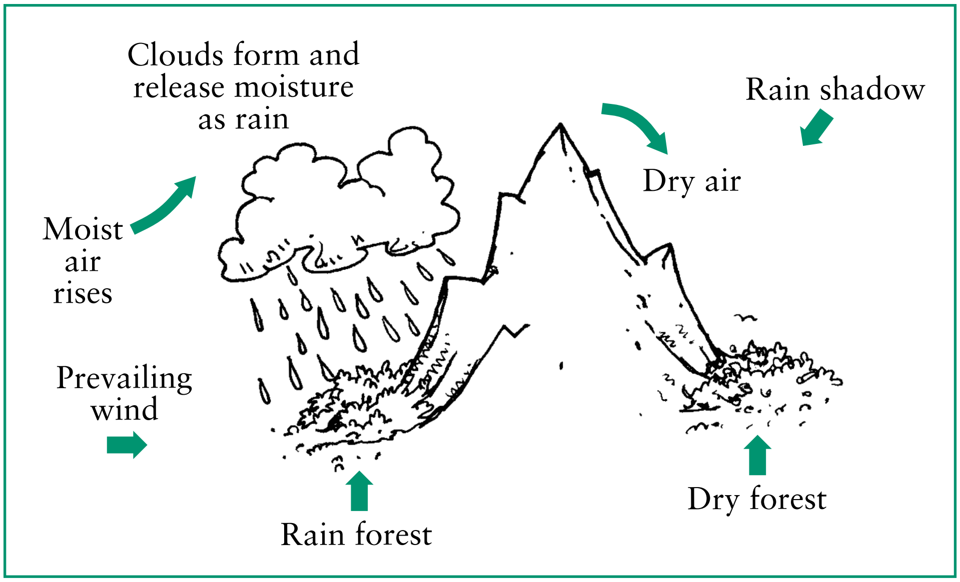


Figure 2. The rain shadow causes some areas to be drier than others.

Figure 3. Guanica Forest, a dry forest in Puerto Rico.

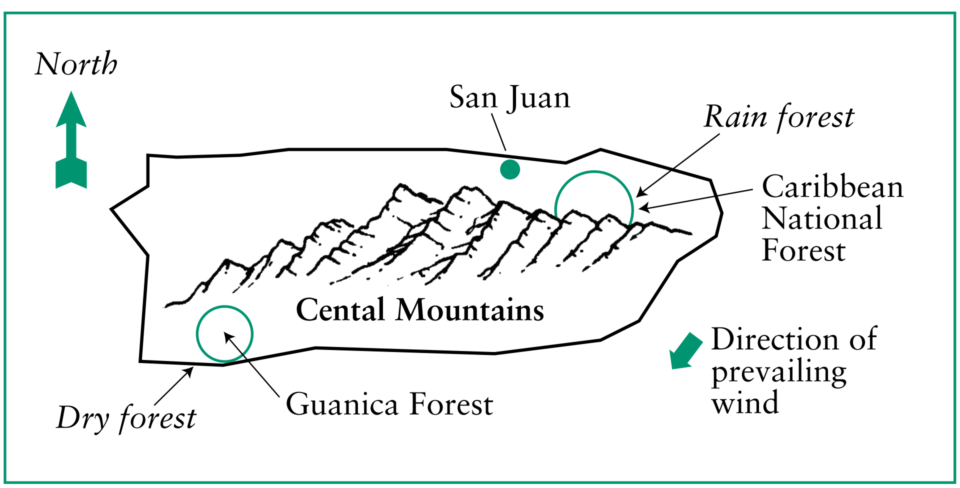


Figure 4 – Location of Guanica Forest in Puerto Rico.

They were interested in the *land use history* of Guanica Forest and the surrounding land. You have probably learned about the history of your country, state, or commonwealth. Land use history is like your country's, state's, or commonwealth's history, except that it is a history of how people used the land.

Reflection Section

- Why do you think it is important to learn the land use history of an area?
- Think about the land that your home or school was built on. What do you think the land was used for, or what it looked like, before your home or school was built there?

Methods

Based on aerial photographs taken in 1936, 1950, 1963, 1983, and 1989, the scientists determined how the land was being used over the years. They looked at the photographs of land within the Guanica Forest and outside of the forest boundaries. They saw that land had been used for buildings, roads, and agriculture. They also saw the natural areas of the forest, including trees, wetlands, and *barren* land. The scientists calculated the percentage of the forest that was in each category. The categories included:

- Urban land (with buildings, parking lots, roads, and other structures)
- Agricultural land
- Water
- Forests
- Wetlands
- Barren land

Reflection Section

- Why do you think the scientists created categories of land use?
- Do you think that the amount of agricultural land within Guanica Forest increased or decreased over the years? Why?
- Do you think that the amount of urban land outside Guanica Forest increased or decreased over the years? Why?

Results

The scientists found that land use had changed over the years. Although the portion of urban land within the forest increased much more than outside of the forest, there were many more hectares of urban land outside of the forest (See Figures 5 and 6). The amount of agricultural land within the forest decreased much more than outside of the forest. Overall, urban land increased and agricultural land decreased, while the amount of forested land stayed about the same. Figure 7 shows some of the actual photographs used by the scientists.

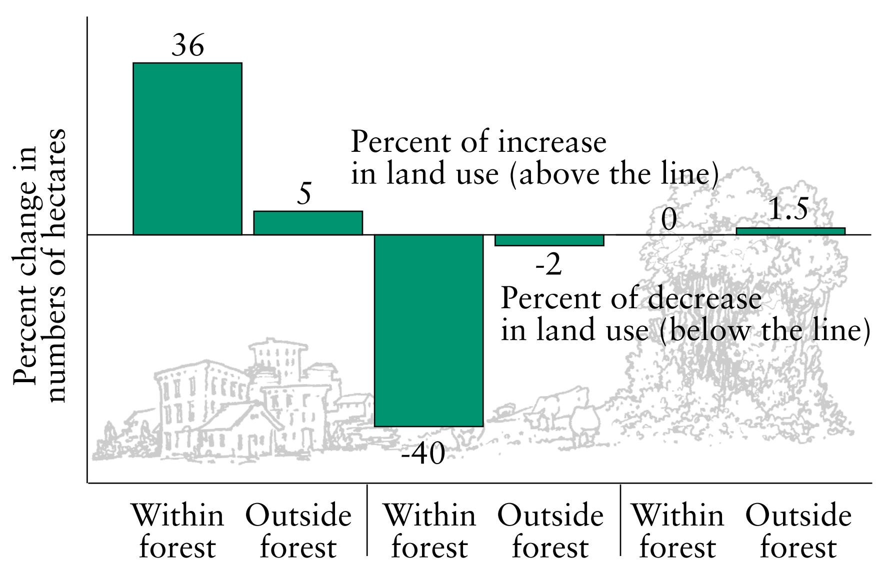


Figure 5. Relative amount of change in land use over time within and outside of Guanica Forest.

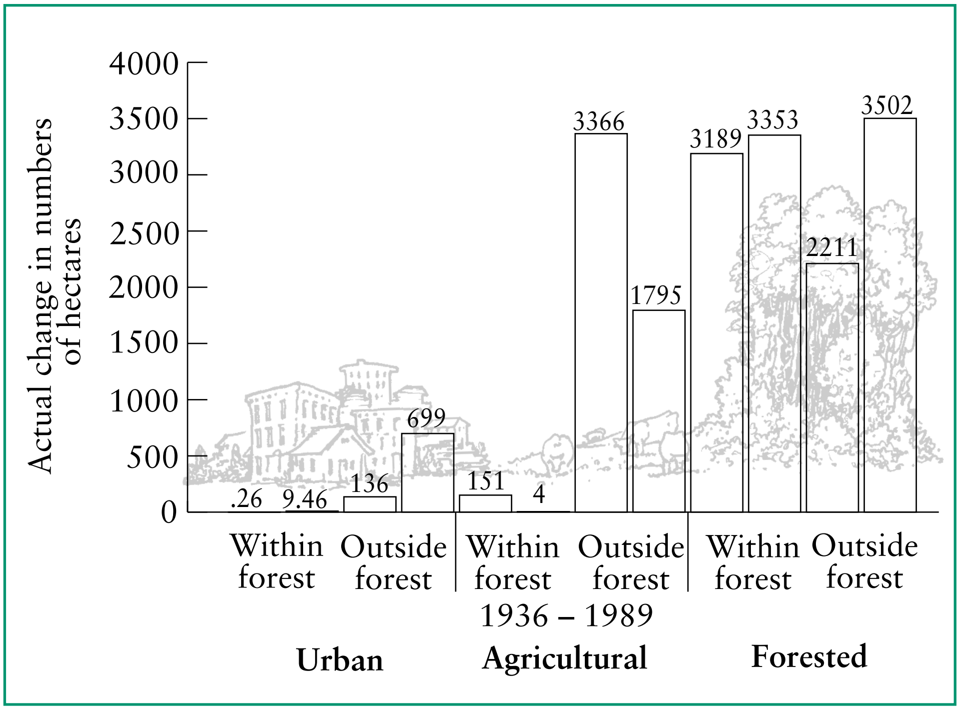


Figure 6. Actual change in number of hectares by land use type within and outside of Guanica Forest. A hectare is a metric measure equal to 2.47 acres.

Figure 7. Aerial photographs showing land use changes over time in an area outside of Guanica Forest.

Reflection Section

- Does the land around your home or school look more like a forest or is it an urban area? What land use changes, if any, are taking place around your home or school?

- Why do you think there is more urban land outside of the Guanica Forest boundary compared with inside the boundary?

Implications

The scientists found that land use outside of Guanica Forest was changing quickly. Urban uses, such as buildings and roads, were replacing the *native* forest. When native forests are removed, animals that do not naturally live in the forest can move into the area. These non-native animals might gradually move close to or over the boundary of Guanica Forest. Once they do that, they will compete with the native animals for food and *habitat*. An example in North America is the European starling, a bird that competes with native American songbirds. The scientists suggest that some of the land surrounding the forest should remain mostly forested with limited buildings or other construction (Figure 8). That way, non-native animals will not be as likely to move into Guanica Forest, and the forest's native animals will be protected.

Reflection Section

- Do you think it is important to protect the native animals in Guanica Forest? Why or why not?

- How could the scientists find out if non-native animals are competing with native animals for food?

FACTivity

In this FACTivity, you will answer the question: Should an area of land outside of the Guanica Forest boundary be closed to land development? The method you will use to answer this question is by holding class discussions. Divide your class into three (or five) equal-sized groups of about 6 students each. One or two groups will take the position that land outside of the immediate forest boundary can and should be developed for human uses. Another group, or two other groups, will take the position that an area of land outside of the forest should be left undeveloped and natural. Each of these groups will develop three arguments in support of their position. You will need to discuss the issue within your group before developing your arguments. Take about 20 minutes to develop your arguments either for or against development. You should consider the advantages of development to people, as well as the disadvantages of development to the animals and plants within the forest. Remember that Guanica Forest has been recognized by the United Nations as one of the best examples of a dry tropical forest. Once you have developed your arguments, each group will present them orally to the remaining group while the whole class listens. The remaining group must decide whether to allow development close to the forest boundary, or whether to create an area around the forest that is closed to human development. The remaining group should spend time in advance planning how they will make their decision. Will they vote, or will they try to reach *consensus*? Once a decision is made, the remaining group must explain to the class how and why they made their decision.

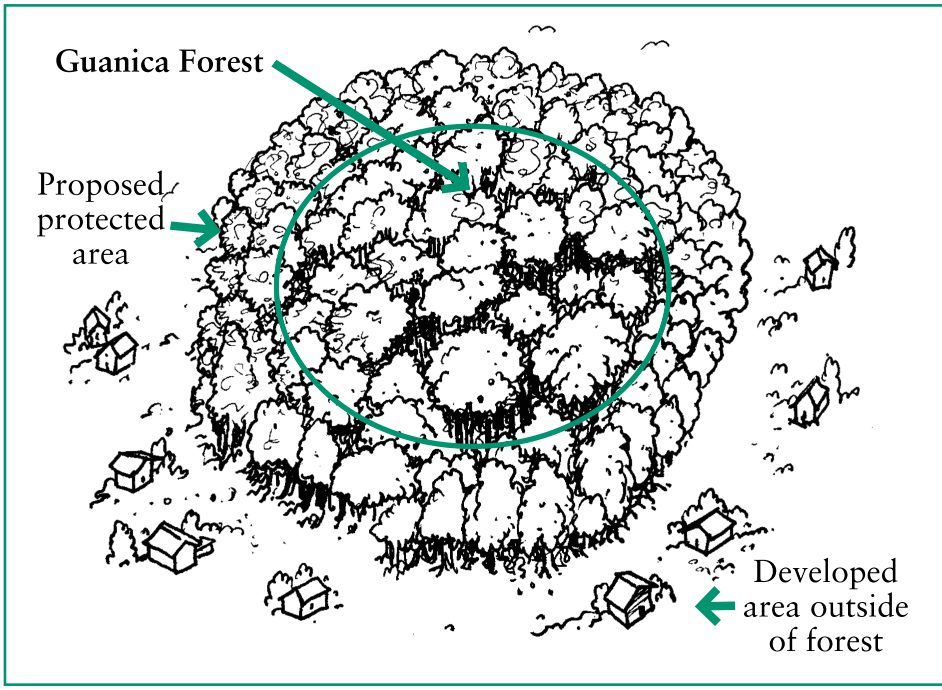
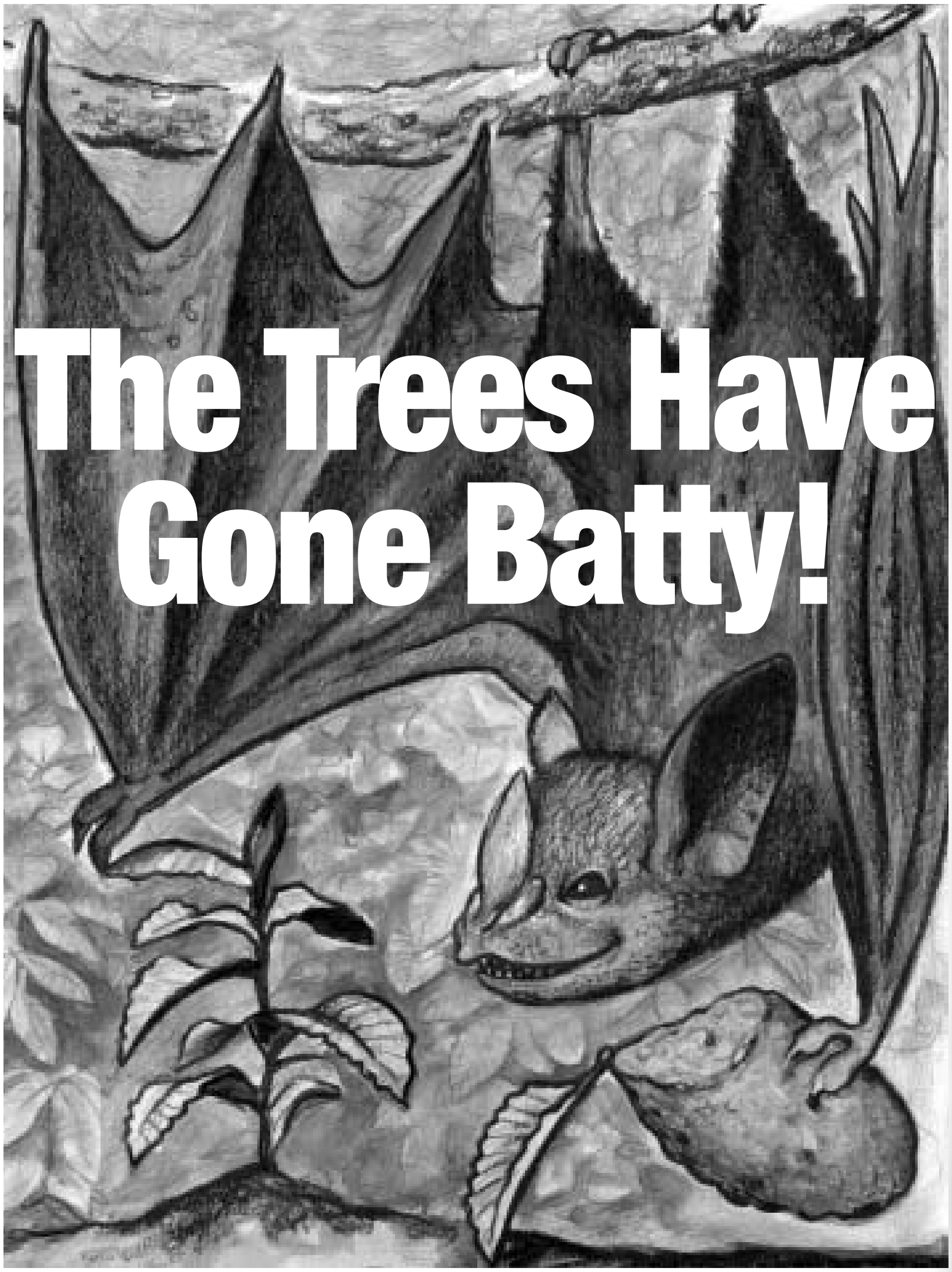


Figure 8. Example of the proposed protected area around Guanica forest.

From Lugo, Ariel E.; Ramos, Olga; Molina, Sandra; and Scatena, F. N. (1996). *A fifty-three year record of land use change in the Guanica Forest Biosphere Reserve and Its vicinity*. Rio Piedras, PR: Institute of Tropical Forestry: USDA Forest Service

For information on dry tropical forests, visit www.mobot.org/gradstudents/olson/drytropics.html

The Trees Have Gone Batty!



How Bat Scat Helped Restore a Tropical Forest

Meet Dr. Parrotta:

I like being a scientist because I get to explore and learn about the natural world. Nature is like a bottomless treasure chest, full of surprises and mysteries. It is fun to try to unravel those mysteries. It is important for humans to find ways to use the gifts of nature without damaging the environment, and also to repair the damage that we have already caused.

Dr. Parrotta

Glossary:

scat (skat): Animal fecal dropping; animal waste.

sample (**sam** pool): A part or piece that shows what the whole group or thing is like.

represent (rep re **zent**): To be an example of.

mine (min): To take coal, ores, or other minerals from the Earth by digging a large hole.

natural resources (**na** cha rôl re sôr sez): A supply of something in nature that takes care of a human need, such as oil.

disperse (di **spürs**): To scatter or spread in all directions.

defecate (**def** uh kat): To get rid of waste matter from the bowels.

infertile (in **fürt** l): Not able to produce crops, fruit, or offspring.

complex (käm **pleks**): Complicated and having many different relationships.

native (**na** tiv): Naturally occurring in an area.

mammal (**mam** ul): Any warm blooded animal with a backbone and glands to produce milk for feeding their young.

diversity (duh **vür** suh te): The quality of being different or varied.

germination (jür mi **na** shun): The act of sprouting or beginning to grow.

Pronunciation Guide

a	as in ape	ô	as in for
ä	as in car	u	as in use
e	as in me	ü	as in fur
i	as in ice	oo	as in tool
o	as in go	*ng*	as in sing

Accented syllables are in **bold**.

Thinking About Science

When scientists want to learn what is happening to a particular piece of land, they usually go out to that place to study what is happening. Because they usually cannot study every inch of a large piece of land, scientists select small areas, or *samples* of land, to study. They assume that the samples *represent* the rest of the land in which they are interested. This same idea is used in most scientific studies. For example, when scientists want to know what the public thinks about something, they cannot ask everyone. They ask a sample of people that the scientists believe can represent everyone. When was the last time you used a sample? When you eat a potato chip from a bag, do you think the rest of the chips in the bag will taste like the first one? Is the first potato chip a sample? Why or why not?

Thinking About the Environment

Humans use land for many things. Sometimes, they want to use land temporarily. In this case, they disturb the land, then they let it grow naturally again. An example of this is when humans *mine* the land for minerals and other *natural resources*. Can you think of other examples of using natural resources that cause a temporary disturbance to the land? Sometimes when the land is disturbed, it cannot restore itself back to its original condition without help from humans and other animals. In this study, the scientists wanted to know whether humans and other animals were helping a tropical forest to restore itself after it had been disturbed by a mining operation.

Jamaican Fruit bat.

Introduction

The scientists in this study were interested in knowing whether humans and other animals can help disturbed areas of land to become healthy ecosystems again. A mining company in Brazil (Figure 1) asked the scientists to restore a tropical forest on their old mining site. The original tropical forest had been cut down to mine the area for

Thinking About Ecology

An ecosystem is made up of all of the plants, animals, bacteria, and nonliving things that occur in a particular environment. When an ecosystem is healthy, the plants, animals, and bacteria depend on each other and on the nonliving environment to live. Some bats, for example, need to eat the fruit of plants to live. When bats eat fruit, they help to *disperse* the seeds of plants. Can you think of how they might do this? When they eat the fruit, they cannot digest the seeds. Because they cannot digest the seeds, they either *defecate* or spit out the seeds. They usually defecate some time after they have eaten the fruit. By that time, they may have flown away from the tree. The seeds fall onto the ground and begin to grow. You can see that the trees help the bats by providing food, and the bats help the trees by dispersing seeds. The bats and the trees depend on each other. They are part of a healthy ecosystem.

bauxite (**bäk** sit) or aluminum ore. Bauxite is the main compound used in making aluminum.

Mining disturbs the land by removing the trees and the top layer of soil, or topsoil (Figure 2). This causes the land to be *infertile*. Since there are no trees left on the land, there is no source of seeds to help trees grow again. Although the scientists could plant some trees, they would never be able to create the kind of *complex* ecosystem that includes all of the original plants and animals. The scientists wanted to know whether they could set up the conditions so that plants and animals could come in from outside the mined area without further human help. Then, the new plants and animals might help the land to become healthy again.

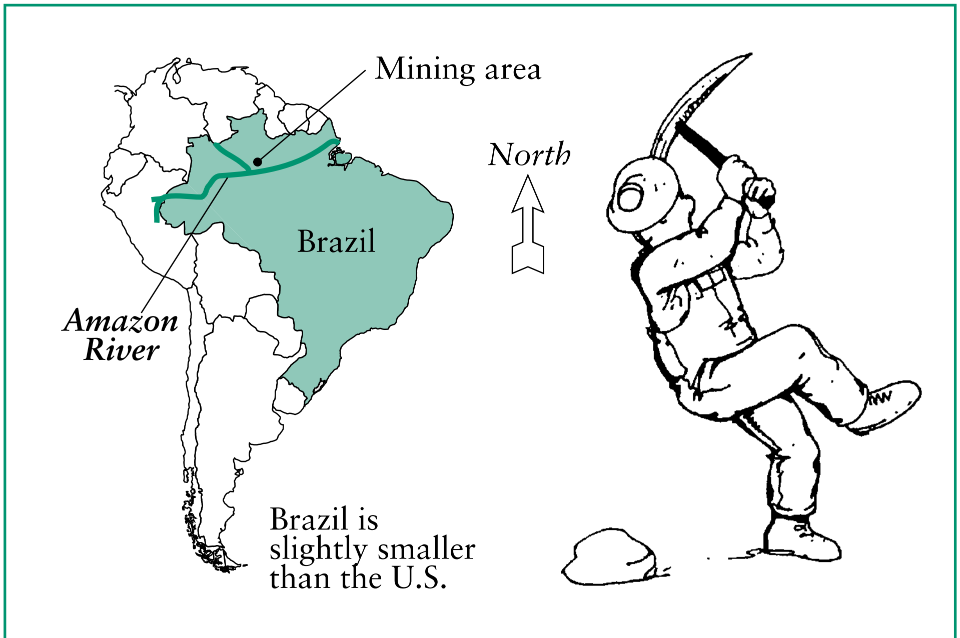


Figure 1. Location of the study area in Brazil.

Figure 2. The mining site.

Reflection Section

- If you were the scientist, what would you tell people you are trying to do through your research on the old mining site?

- Although trees are not mobile, their seeds can spread to new areas and grow. Can you think of two ways that a tree's seeds can move from place to place?

Methods

The scientists covered the bare ground with new topsoil and planted 70 different kinds of *native* trees. Although this seems like a lot of different kinds of trees, it is not a lot for a tropical forest in Brazil. Brazilian tropical forests can have thousands of different kinds of trees! Then, the scientists waited 10 years for the trees to grow. At the end of 10 years, the scientists selected 32 sample areas to study. The areas they studied were circles, each 10 meters in diameter (To find out how many yards this is, multiply 10 times 1.09).

The scientists went into these sample areas and identified the kind of trees growing in each circle. They also counted how many of each kind of tree was growing. The scientists determined which of the trees were over 10 years old. The scientists then knew that the rest of the trees had grown on their own over the last 10 years. The scientists recorded the number and kind of birds and *mammals* they found within the sample areas. They collected all of this information by observing and carefully recording everything that they saw.

Reflection Section

- Why did the scientists want to identify which trees they had planted 10 years ago and which trees had grown on their own?
- Why do you think that the scientists wanted to know the kind and number of birds and mammals within the sample areas?

Results

The scientists found that the numbers and kinds of new trees growing in the sample areas were different, depending on where the sample area was located. The sample areas that were close to the outer edge of the mined area, near existing tropical forests, had a greater *diversity* of tree species (Figure 3). The scientists counted 125 different kinds of trees. They also had more trees growing in them than the

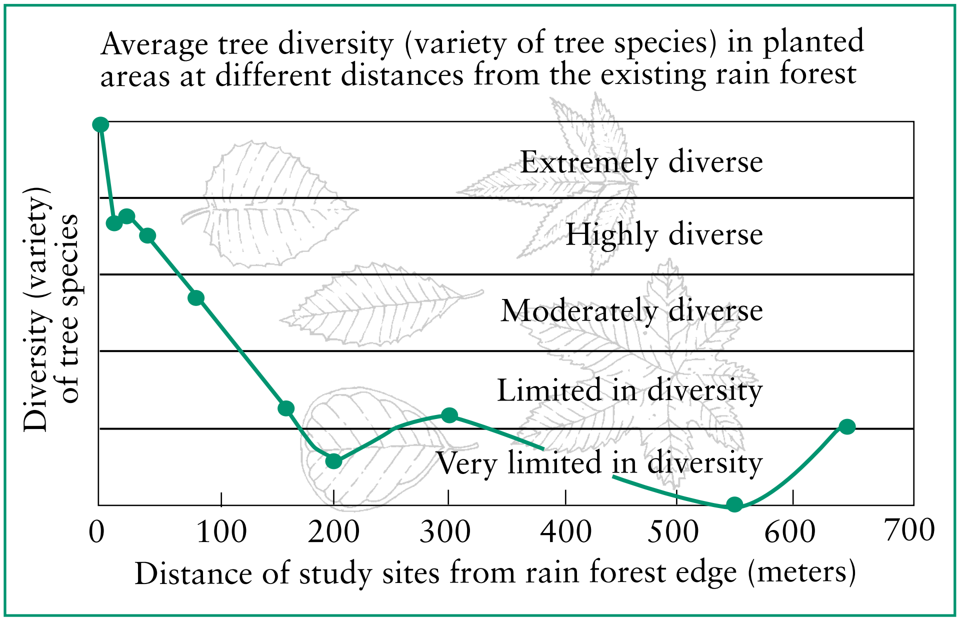


Figure 3. The amount of tree diversity at different distances from the rain forest.

sample areas near the center of the mined area. The scientists found 45 different kinds of birds in the sample areas. Of these, less than half would have been able to successfully disperse seeds. That is because most of the birds ate insects or nectar, or would have been able to digest the seeds. (Think of parrots and parakeets. They eat and digest seeds, so they would not be good at dispersing seeds!)

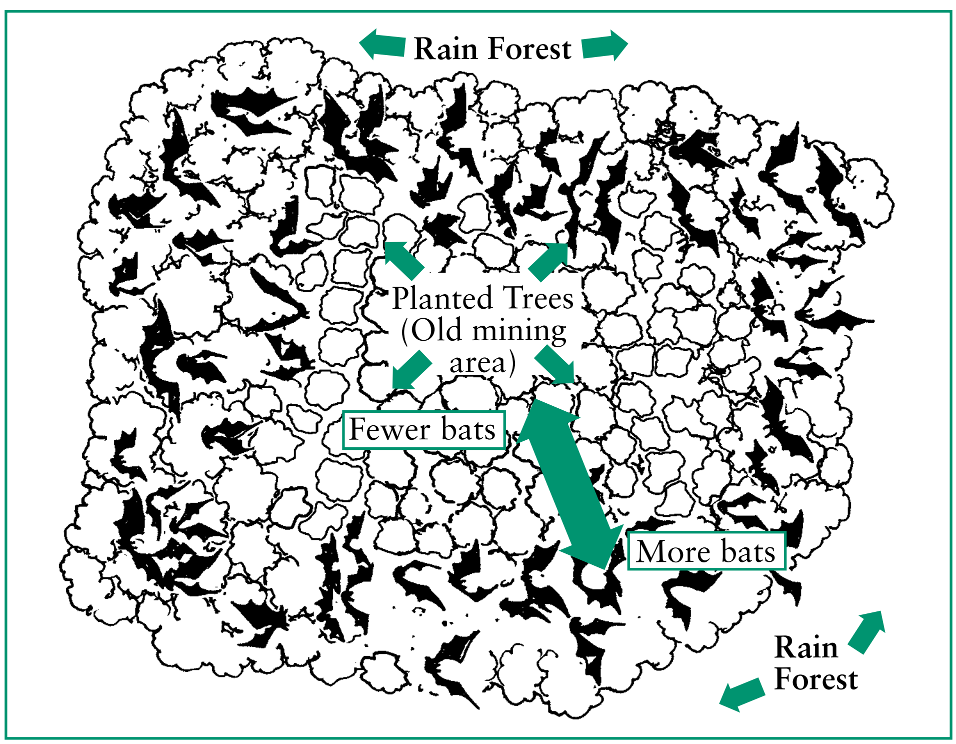


Figure 4. The relationship of the planted forest to the existing rain forest.

The scientists found that a lot of different kinds of mammals lived in the sample areas. The most numerous kind of mammal found in the sample plots was fruit bats. There were more bats in the sample areas closer to the edge of the mined area than in sample areas closer to the center (Figure 4). Although there was not a great diversity of different kinds of bats, there was a large number of fruit bats living in the sample areas. Figures 5 and 6 show how vegetation began growing on the old mining site.

Reflection Section

• Where the scientists found a diversity of new kinds of trees growing, they also found a large number of fruit bats. If you were the scientist, what would you conclude from this information?

• Why do you think that there were more bats and more kinds of new trees near the edges of the old mining area, and fewer bats and fewer kinds of trees near the center?

Figures 5 and 6. The recovering mining site. The roads you can see throughout the area are for transporting soil and seedlings. Eventually, these roads will grow naturally with vegetation and the entire area will become a forest again.

Implications

The scientists concluded that by planting a variety of trees on an old mining site, nature can take over and help the land to become a healthy ecosystem. The scientists believe that by planting the trees, they started a process that might have taken decades or centuries to happen on its own. Once they planted the trees, animals were able to move into the young tropical forest. When bats arrived, they defecated seeds eaten from fruit trees outside of the mined area. The bats helped to make the young tropical forest more diverse, which provided more food for other kinds of animals. After humans have disturbed land, they might have to help restore the environment to a healthy condition. Usually if humans lend a helping hand in the beginning, nature can take over the job.

Reflection Section

• Do you think that it is best to let nature take over the job of restoring an ecosystem to a healthy condition? Why or why not?

- Can you think of other ways that plants and animals depend on each other in the natural environment? What do trees and other plants provide to animals? What do animals provide to plants?

FACTivity

In this article, you learned how bat scat helped trees to reproduce. For this FACTivity, you will be answering the question: What other benefits does animal scat offer to trees and plants? To do the FACTivity, you will need:

- Four 4-inch plant pots with saucers
- A bucket of soil dug from your school yard—be sure to break up any clumps and remove any grass or plants, including plant roots and rocks or pebbles
- An extra bucket for mixing soil
- A small bag of manure (may be purchased at a garden shop) or a small bag of worm castings (may be purchased at a garden shop)
- A bag of bean seeds (may be purchased at a garden shop)
- A cup or a small shovel
- Masking tape and marker
- Ruler or other type of measuring stick

Before you start, you need to know what manure and worm castings are. Can you guess? Both are animal wastes. Manure is the waste from animals like cows and horses. You should be able to guess which animal produces worm castings!

The method you will use is this: Fill two of the pots with the soil from your school yard to within a few centimeters (or inches) from the top. Be sure to wear rubber gloves when you handle the soil! Label the pots "school yard" with masking tape and the marker. Take a shovelful or cupful of soil from your school yard bucket and place it in the extra bucket. Mix in a shovelful or cupful of manure OR worm castings and mix well with the cup or the shovel. Mix enough schoolyard soil

Table to be completed weekly. You will create four of these, one for each week.

Date:	Height of bean 1	Height of bean 2	Height of bean 3	Average height of the three beans
School yard #1				
School yard #2				
Manure #1				
Manure #2				

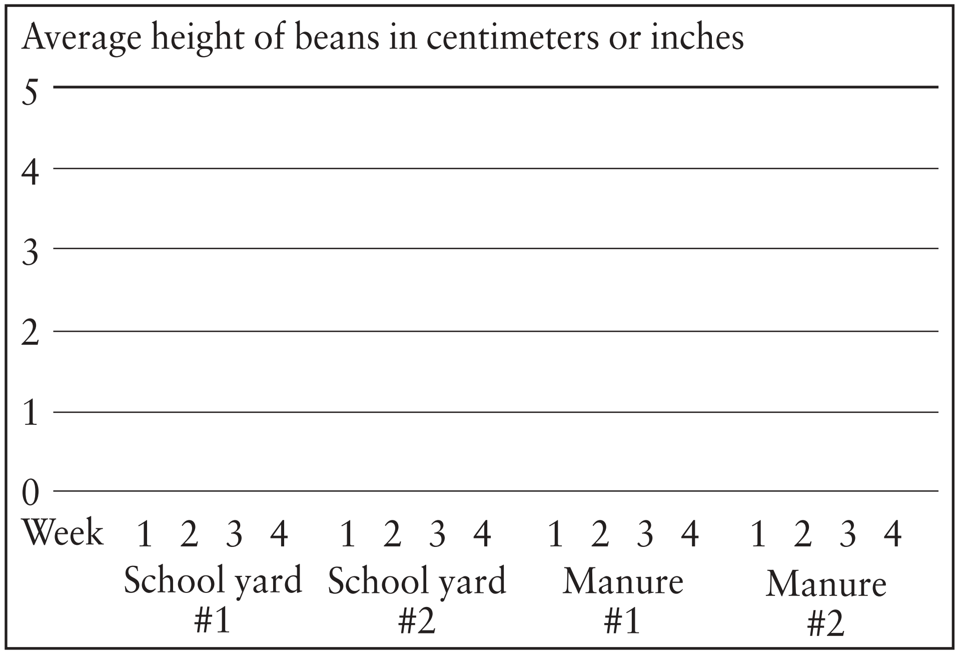
Summary table. Average height of all bean plants over 4 weeks

Date:	Average height of beans Week 1	Average height of beans Week 2	Average height of beans Week 3	Average height of beans Week 4
School yard #1				
School yard #2				
Manure #1				
Manure #2				

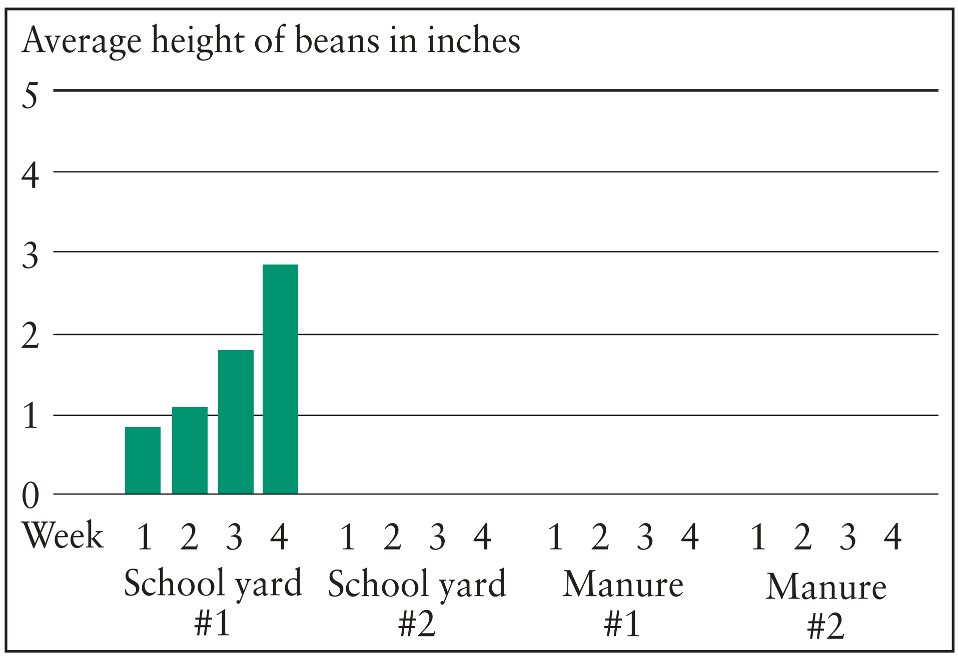
and manure (or worm castings) to fill the next two pots to within a few centimeters (or inches) of the top. Label the pots “manure” or “worm castings” using the masking tape and marker. Make three thumbprints about 2 centimeters deep (or about 1 inch deep) in each pot. Space the thumbprints so that they form a triangle. Place one seed in each thumbprint. Cover the seeds with soil from the pot and gently water.

Put the pots in a sunny window and keep the soil moist. Do not over water! Observe the pots every day for 4 weeks. You can use the chart on the previous page as an example. At the end of each week, measure the growth of the beans. Keep a weekly record of your observations. You will need to calculate the average height of the beans in each pot. To calculate the average, add the height of the three bean plants and divide the total height by three. You can easily compare your data by creating a bar chart (or histogram). To learn how to create a bar chart, see the example at the bottom right. Which kind of soil is best for seed germination and growth? Think about what you learned in this article. Bats helped trees to reproduce by spreading tree seeds through bat scat. What other benefits does animal scat offer to plants? This experiment should help you answer this question.

Sample bar chart: Average height of beans over 4 weeks. (Create this bar chart from the summary table on the previous page. See the example that follows.)



Example bar chart: Average height of beans over 4 weeks.



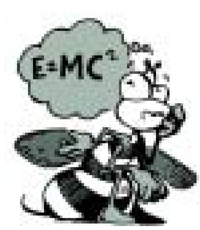
From Parrotta, John A., Knowles, Oliver Henry, and Wunderle, Joseph M. Jr. (1997). Development of floristic diversity in 10-year-old restoration forests on a bauxite mined site in Amazonia. *Forestry Ecology and Management*. 99: 21-42.

I'll Huff and I'll Puff and I'll Blow Your Trees Down!

Meet Dr. Francis:

I like being a scientist because I have an enormous curiosity about nature, and science gives me an opportunity to be personally involved in the unraveling of its mysteries.

Dr. Francis



Thinking About Science

When scientists study something, they usually like to plan their experiments in advance. They do this so that they have more control over the experiment. When scientists study *natural* *disasters*, they cannot always plan their experiments. This is because people do not always know when or where a natural disaster will occur. Natural disasters include events like hurricanes, tornadoes, landslides, volcanoes, and floods. The scientists in this study wanted to study the effects of a hurricane. As part of their research, they needed to know

Thinking About Ecology

In the natural world, feedback and control are important principles to understand. Feedback is a response to something that occurs, and its result is usually some kind of control on the system. Feedback can be positive as when it accelerates (ak **sel** ür ats) a process, or negative when it slows down a process. In this study of hurricane damage, feedback was provided by trees. In response to the hurricane's strong winds, the trees shed their leaves. Once the trees lost their leaves, the hurricane's winds could no longer do much more damage to the trees. This provided some control by limiting how much more damage the wind could do to the trees. Can you think of examples of feedback and control in your own body?

the wind speed of the hurricane as it blew across different places. Because they did not know where or when the hurricane would blow, they had to rely on measurements made by other people. You can see that scientists sometimes have to use *data* collected by other people. Can you think of examples of when you have to do the same thing? (Hint: Think about the weather forecast or about medical information. What other different kinds of information do you use that are collected by other people?)

Thinking About the Environment

In nature, some events are *cyclical*. The seasons are an example of a cyclical natural event because they repeat themselves every year. Day and night are also examples of a cyclical event because they are repeated daily. Can you think of other cyclical events that are *predictable*? Cyclical events happen in nature all of the time. Some cycles are not as exact as other cycles. Hurricanes, for example, are cyclical because they occur in the tropics every year between June and November. However, we do not know exactly what day a hurricane will occur during that time. Can you think of other cyclical events that are not as easily predictable?

Glossary:

natural disaster (**nach** ur ul di **zas** tür): A natural happening that causes much damage or suffering.

data (**da** tuh): Factual or measurement information.

cyclical (**sik** lik ool): Like a cycle; when events continue to happen in the same order.

predictable (pre **dik** tüh bül): Easy to tell what one thinks will happen in the future.

feedback (**fed** bak): A response, often one that sets a process in motion. The response can then also be affected by the process it set in motion.

species (**spe** sez): Groups of organisms that resemble one another in appearance, behavior, chemical processes, and genetic structure.

compacted (käm **pak** ted): Closely and firmly packed together.

analyze (**an** ä liz): To study or examine carefully.

modify (**mäd** uh fi) To make a small change in.

Pronunciation Guide

a	as in ape	ô	as in for
ä	as in car	u	as in use
e	as in me	ü	as in fur
i	as in ice	oo	as in tool
o	as in go	*ng*	as in sing

Accented syllables are in **bold**.

Introduction

When a hurricane occurs, a lot of damage can be done to buildings and other structures. One of the most visible types of damage occurs to trees. When hurricanes occur, trees lose most of their leaves. The scientists in this study wanted to know more about the extent of damage to trees following a tropical hurricane in Puerto Rico (Figure 1). When Hurricane Hugo occurred in September of 1989, the scientists decided to study the damage done to the trees in Puerto Rico (Figure 2). Hurricane Hugo was a category 4 hurricane (Table 1).

Caribbean hurricanes are formed at the West Africa coast. Atmospheric conditions push hurricanes to the islands in the Caribbean Sea and up the east coast of the United States (Figure 3).

Figure 2. Tree damage following Hurricane Hugo.

Reflection Section

- The scientists knew that overall, Hurricane Hugo had winds of between 131-155 mph (210-249 kph). Why do you think they wanted to measure wind speed at different places in Puerto Rico?
- Do you think that hurricane damage to a tree with leaves is greater than to a tree without leaves? Why or why not?

Method

The scientists wanted to understand how much tree damage was done by the

Figure 1. Location of Puerto Rico

Category	Wind speed
1	74-95 mph/ 119-153 kph
2	96-110 mph/ 154-177 kph
3	111-130 mph/ 178-209 kph
4	131-155 mph/ 210-249 kph
5	156+ mph/ 250+ kph

Note: If you want to convert miles per hour (mph) to kilometers per hour (kph), multiply the number of mph X 1.61. To convert from kph to mph, multiply the number of kph X .621.

Table 1. Saffir-Simpson Hurricane Scale

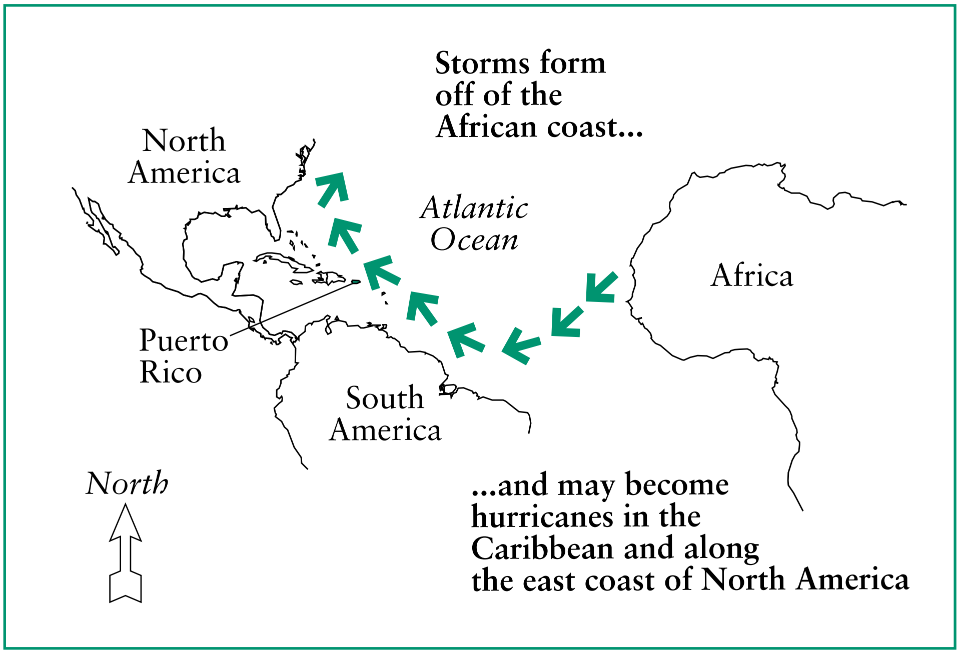


Figure 3. Tropical hurricanes in eastern North America begin as tropical storms on the west African coast.

hurricane at different wind speeds. To do this, they had to study the trees in areas where wind instruments were placed before Hurricane Hugo occurred. The scientists observed 81 different *species* of trees in 18 different areas. They observed damage to 1,226 trees. The scientists put each of the trees in one of five categories, based on how much damage they observed. They then compared palm trees with broad-leafed trees, to determine whether one kind of tree had more damage than the other (Figure 4). For the palms and the broad-leafed trees, they compared the amount of damage with the wind speed.

Figure 4. Palm and broad-leafed trees.

Reflection Section

- Why did the scientists study trees that were located near wind instruments?

- Look at the leaf shapes in Figure 4. Do you think the scientists found a difference in damage to trees with different kinds of leaves? Why or why not?

Results

The scientists found out many things about the harm done to trees during Hurricane Hugo. First, they found that larger trees had more damage than smaller trees. They also found that palm trees had less damage than broad-leafed trees. They also discovered that after broad-leafed trees lose their leaves to the wind, there is less damage to the trees. Up to a point, the hurricane's winds continued to do more damage as they blew faster. However, when the wind blew over 100 kph (multiply 100 by .621 to find out how fast this is in miles per hour), it did not do much more damage (Figure 5). By then, most of the leaves had blown off of the trees.

Reflection Section

- Why do you think the palm trees had less damage than the broad-leafed trees?

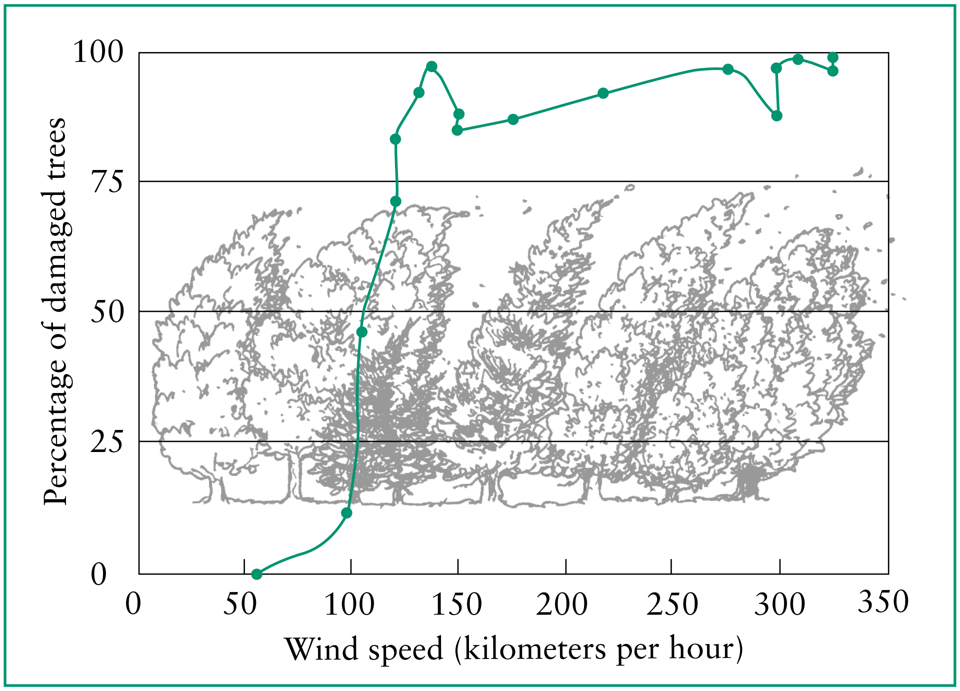


Figure 5. Most of the damage to trees happens when winds blow up to 100 kilometers per hour.

- With your class, discuss whether anyone has ever seen a tree that has been blown over or broken by the wind. How tall was the tree? How big was its trunk? Are there any similarities among the damaged trees seen by your classmates? What are the similarities?

Implications

Where hurricanes can occur often in an area, people must be careful where they plant trees or locate their homes and other buildings. Trees should only be planted in deep, well-drained soils that are not *compacted*. If a hurricane is coming, a broad-leafed tree might be protected by cutting off its leaves. Hurricanes are cyclical natural events in the Caribbean and the Eastern United States. Because they cannot be controlled, people must learn to live with them.

Reflection Section

- Should people who live in areas where hurricanes occur build their homes next to big broad-leafed trees? Why or why not?

- Hurricanes might cause damage to buildings and some trees. Do you think there are any natural advantages to hurricanes? Why or why not? If you think there are advantages, what might they be?

FACTivity:

The scientists in this study had to rely on instruments that were near, but not at, their study areas. They also had to rely on instruments that were maintained by other people. In this FACTivity, you will answer the question: Can weather measurements made by other people in distant places be accurate for another area or situation? We use such measurements every day, such as when we hear local reports of the current temperature. This FACTivity will help you think about whether you can trust weather measurements that are not made exactly where you are located. The method you will use to answer the question is as follows: Get an outdoor thermometer and place it outside in the shade. Observe and record the temperature every afternoon, for a week, at the same time of the day. You can use the example on the next page as a guide. Before beginning your observations, find another source for the current temperature in your city or town. You may be able to call a special phone number, the local airport, a local radio station, search the internet, or use a weather radio. Record the reported temperature for the same time (or within 1 hour of the same time) as your observed temperature, using the chart on the next page as a guide. To help you *analyze* the differences between observed and reported temperatures, you will create a bar chart from your table (See an example of a bar chart at the end of the first FACTivity). Now compare the

Sample chart for recording temperatures.

	Monday	Tuesday	Wednesday	Thursday	Friday
Observed Temperature (F or C)					
Reported Temperature (F or C)					

temperature you observed on your thermometer with the reported temperature. Are the two daily temperatures the same or different? Do you think the reported temperature is an adequate measure of the temperature at your school? Why or why not?

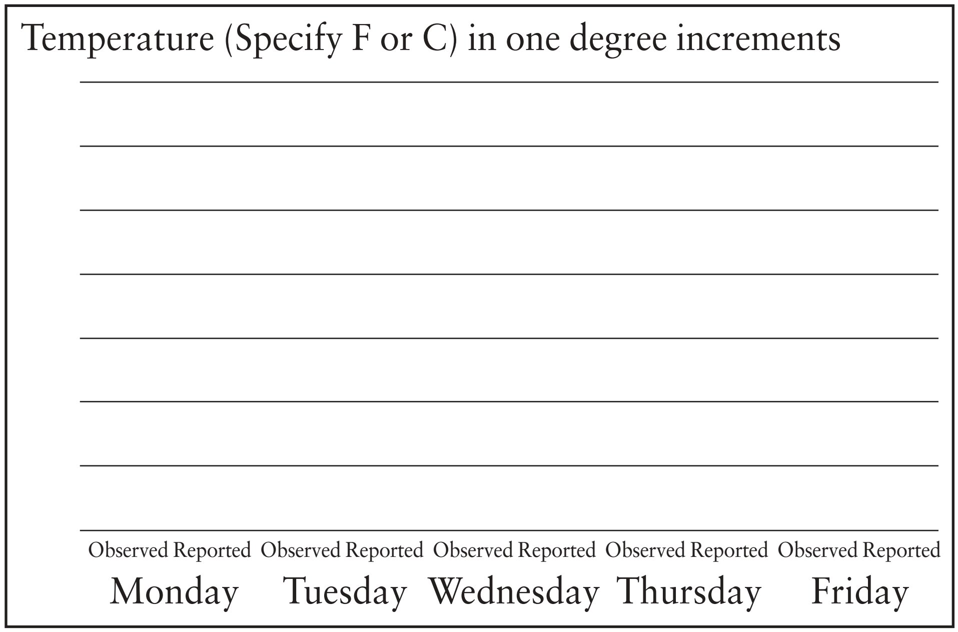
You may also record the observed and reported temperature at different times throughout the day for the week. The more observations you have to compare, the more accurate your findings will be. If your findings are more accurate, will you have more or less confidence in your answer to the FACTivity question? Why?

Convert your temperatures from Centigrade to Fahrenheit or from Fahrenheit to Centigrade. Then make a new bar chart using the converted measurements. Compare the bar charts. How are they similar? How are they different? This is how you do the conversion:

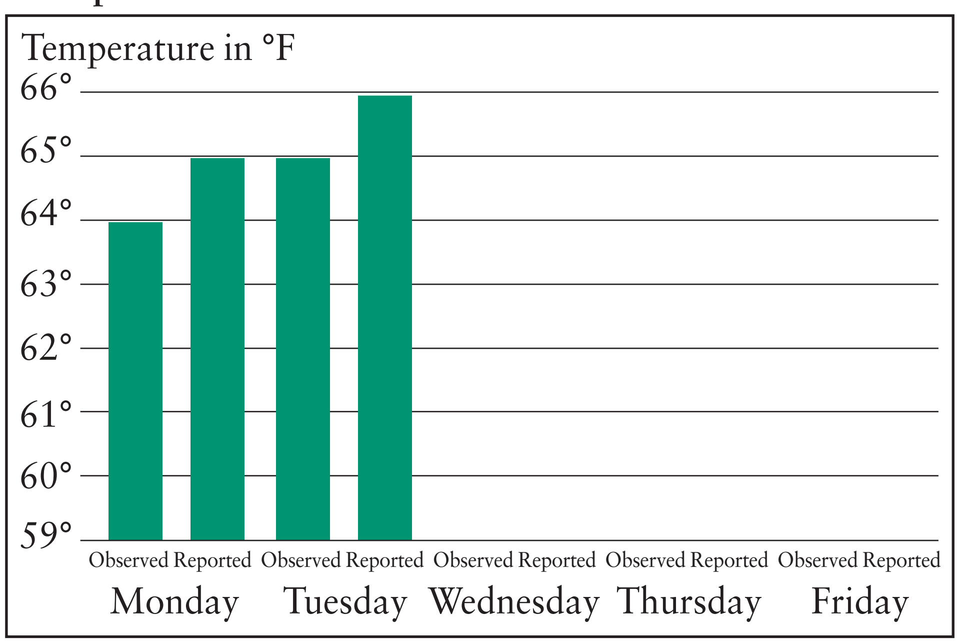
If you know Fahrenheit: Subtract 32 from the temperature, then multiply by .55

If you know Centigrade: Multiply the temperature by 1.8, then add 32

Sample bar chart (histogram) for analyzing temperatures.



Example of a bar chart



Another FACTivity!

Want to measure wind speed the old-fashioned way? Here's a *modified* version of a scale developed to help British sailors estimate wind speed in the days before wind instruments were available. Why do you think the British sailors could not have used this scale, the way it is presented here? (Hint: Where would British sailors be when they needed to estimate wind speed?) What part of the scale has been modified?

Speed in mph	Name	Common Effects
0-1	Calm	Smoke rises straight up
1-3	Light air	Smoke drifts
4-7	Light breeze	Feel it on your face and see leaves rustle
8-12	Gentle breeze	Leaves on the move and flags wave
13-18	Moderate wind	Dust, leaves, and paper fly. Branches move
19-24	Fresh wind	Small trees sway
25-31	Strong wind	Large branches move. Whistles through wires
32-38	Gale	Trees sway. Hard to walk
39-46	Fresh gale	Twigs snap off trees
47-54	Strong gale	Branches break. Shingles blow loose
55-63	Storm	Trees break. Buildings damaged
64-72	Violent storm	Widespread damage
73-Higher	Hurricane	Extreme damage
From: Cox, J. D. (2000). Weather for dummies. Foster City, CA: IDG Books, p. 90.		

From Francis, John K. and Gillespie, Andrew J. R. (1993). Relating gust speed to tree damage in Hurricane Hugo, 1989. *Journal of Arboriculture*, 19(6): 368-373.

Which National Science Education Standards* Can Be Met by the *Natural Inquirer?*

Science Education Standards* / *Articles* →	Swimming Upstream Without a Ladder	Leaf Me Alone!	Oooooh! That's Growth!	It's a Gas!	Please Join Us for Dinner	Some Things Will Always Change	The Trees Are Going Batty!	I'll Huff and I'll Puff and I'll Blow Your Trees Down!
Science as Inquiry								
Abilities Necessary for Scientific Inquiry	X	X	X	X	X	X	X	X
Physical Science								
Properties of Matter				X				
Transfer of Energy		X		X			X	
Life Science								
Structure & Function of Living Systems		X		X	X	X		
Reproduction & Heredity	X						X	
Regulation & Behavior	X	X						X
Populations & Ecosystems	X	X	X	X	X		X	X
Organism Diversity & Adaptation					X		X	X
Earth & Space Science								
Structure of Earth System				X		X	X	X
Earth in the Solar System		X						X
Science & Technology								
Nature of Technological Solutions	X					X		
Tradeoffs of Technology	X							
Benefits and Consequences	X			X				
Science–Personal & Social Perspectives								
Personal Health				X				X
Natural Hazards				X				X
Risks & Benefits				X		X		X
Science & Technology in Society	X							X
History & Nature of Science								
Science as a Human Endeavor	X	X	X					
Nature of Science				X	X			

*National Research Council, Content Standards, Grades 5-8

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. These are large areas of trees, streams, and grasslands. National forests are similar in some ways to national parks. Both national forests and national parks provide clean water, homes for animals that live in the wild, and places for people to do fun things in the outdoors. National forests also provide resources for people to use, such as trees for lumber, minerals, and plants used for medicines. Some people in the Forest Service are scientists, whose work 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 natural environment is healthy, now and into the future.

USDA
United States Department of Agriculture

Forest Service

FS-726 • December 2001

Visit these Web sites for more information:

USDA Forest Service:
http://www.fs.fed.us

The Natural Inquirer:
http://www.naturalinquirer.usda.gov

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

USDA Kid's Page:
http://www.usda.gov/news/usdakids/index.html

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

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

Smokey Bear:
http://www.smokeybear.com

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

National Forest Recreation:
http://www.fs.fed.us/recreation/recreation.html

International Institute of Tropical Forestry:
http://www.fs.fed.us/global/iitf