

Natural

INQUIRER

Number 16

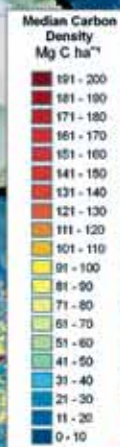
THE

HAWAII

PACIFIC-ISLANDS
EDITION

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Mauna
Kea

Mauna
Loa



Natural Inquirer

Hawai'i-Pacific Islands Edition • Number 16 • Spring 2012

Produced by

Forest Service

Cradle of Forestry in America
Interpretive Association

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With thanks to

Ann Bartuska, Deputy Under
Secretary, USDA Research,
Education, and Economics, who
provided the idea, inspiration,
and support for this Hawai'i-
Pacific Islands edition.

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Hawai'i Volcanoes National Park

Cover mural: Friends of the Ka'ūpūlehu Dryland
Forest program: Ho'ola Ka Makana'a and
Kealakehe Dryland Forest. Support: HFIA HFI, KS-
'Āina Ulu, Naelehele, & FOCUS mural collaboration.
Concept & Design: Yvonne Yarber Carter, Leah
Ingram, Pua Whitehead. Mural painters: Hui Ho'ola
Ka Makana'a & Hui La'au Kama'aina (Group for the
native plants), ages 7-60.



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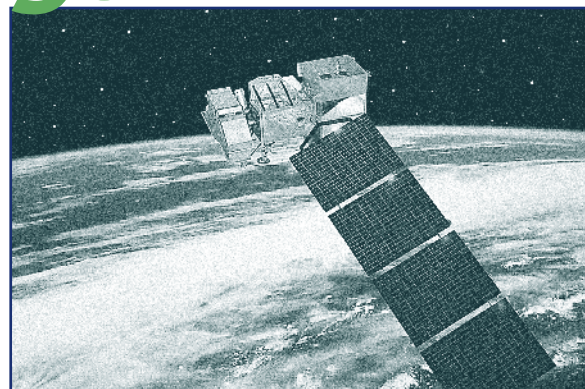
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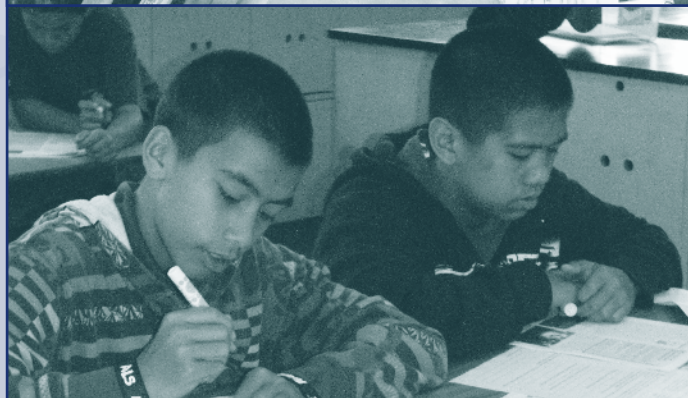
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Editorial Review Board



Natural Inquirer editorial review board hard at work.

Hawai'i Pacific-Islands Editorial Review Boards' Comments

"Many different types of measurement are used in science." (Mangrove Mania)

"It was interesting and educational."

"I think that this is a great article, but it would have been better with the colors." (Beam Me Down, Scotty)

"It was a very educational article. Thank you."

"Some of the Hawaiian words are confusing."

"It's a good magazine."

"It is very good, and I learned a lot of things."

"I learned what mangrove forests are and what they provide."

"The most important thing I learned in this article is how endangered the dry forests are."

"Koa is one of the most valued tropical wood."

"This was very easy for me to understand the work they did, and I enjoyed reading the material."

"Needs color! More pictures!" (Treasure Islands)

"It's important so that people stop damaging native forests."

"I liked the pictures, and it was good." (Left High and Dry)



**Laupahoehoe High and Elementary School,
Laupahoehoe, HI**



View from the school's front door.

About the *Natural Inquirer*

Scientists report their research in journals, which are special magazines 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 about scientific research conducted by scientists in the Forest Service, U.S. Department of Agriculture. If you want to know more about the Forest Service, you can read about it on the inside back cover of this journal, or you can visit the *Natural Inquirer* Web site at <http://www.naturalinquirer.org>.

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 Scientists” 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, which 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. Look at the glossary and the special sections highlighted in each article for more information. A Hawaiian glossary is on page 106. This edition of the *Natural Inquirer* includes a new section. At the end of each article, you will learn something special about the culture of Hawai‘i and the Pacific Islands. Did you know, for example, that Hawaiians have been surfing ocean waves for thousands of years?

At the end of each section of the article, you will find a few questions to help you think about what you have read. Your teacher may use these questions in a class discussion.

Who 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**—Are you interested in learning?
- 🍁 **Be enthusiastic**—Are you enthused about an environmental topic?
- 🍁 **Be careful**—Are you accurate in everything that you do?
- 🍁 **Be open minded**—Are you willing to listen to new ideas?
- 🍁 **Question everything**—Do you think about what you read and observe?

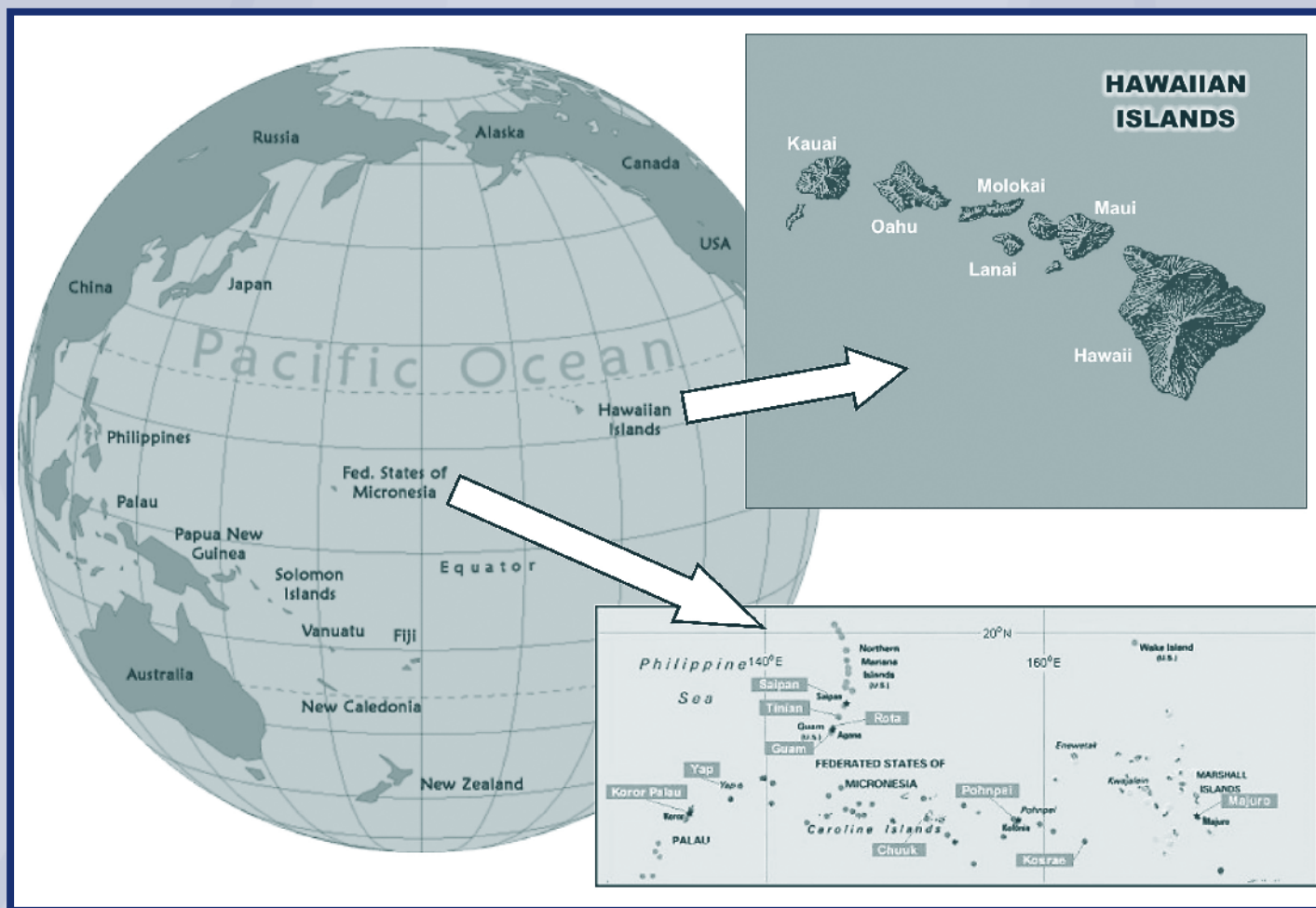
Welcome

to the Hawai'i-Pacific Islands edition of the *Natural Inquirer*!

Sitting in the tropical zone of the Pacific Ocean, Hawai'i and the Pacific Islands are special places. Because these islands lie close to the equator, their coastal climate is warm all year. The youngest islands were created by volcanoes and have mountains that sometimes get snow! Take a look at the map below to locate the Hawaiian Islands and the Federated States of Micronesia (FSM). Find the largest of the Hawaiian Islands. The entire State of Hawai'i takes its name from this largest

island. Five of the articles in this *Natural Inquirer* describe research that scientists did on the island of Hawai'i. One article describes research done on two islands in the FSM. The FSM is an independent country made up of hundreds of small islands.

The research you will read about in this *Natural Inquirer* was conducted by scientists working at the Institute of Pacific Islands Forestry, or IPIF. Located in Hilo, HI, scientists at IPIF study a range of environmental topics in Hawai'i and the Pacific Islands.



The Pacific Ocean and the Pacific Islands. Images courtesy of http://free-extras.com/images/pacific_ocean_globe-12033.htm, <http://www.chachasconeyisland.com>; and the National Oceanic and Atmospheric Administration.

The Hawaiian Language

Occasionally, you will come across Hawaiian words in this *Natural Inquirer*. Hawaiian words are in *italics*. For more information about the Hawaiian language and for a glossary and pronunciation of these words, see page 106.

This *Natural Inquirer* was created with the help of two Native Hawaiian AmeriCorps volunteers. AmeriCorps is a group of U.S. Federal job programs. AmeriCorps gives adults of all ages the opportunity to address important needs by working within communities. James Akau and Leila Kekuewa worked with middle school students at *Laupahoehoe* High and Elementary School, did research, and wrote sections of this journal. All of this was done as a part of their AmeriCorps experience.

The Hawaiian Islands

Let's learn about the Hawaiian Islands. These islands are the most remote group of human-populated islands in the world. Hawai'i is 3,857 kilometers (2,397 miles) from California and 6,195 kilometers (3,850 miles) from Japan. The Hawaiian Islands extend more than 2,413 kilometers (1,500 miles) across the Pacific Ocean. Because the Hawaiian Islands are so remote, many of the **native** plants and animals living there are unique. These plants and animals arrived on their own, traveling by wind, wings, or waves. Over hundreds of thousands of years, these plants and animals evolved into **species** found nowhere else on Earth. More than 90 percent of Hawaiian native species are found only in Hawai'i. For example, the State bird of



James Akau is an expert in Hawaiian plants and Native Hawaiian culture.



Leila Kekuewa is giving the shaka hand signal while caring for plants in a greenhouse. In Hawai'i, this signal means, "Hello. Everything is good. Take care of yourself."

Hawai‘i, the *nēnē* goose, may have evolved from Canada geese that landed in Hawai‘i thousands of years ago.



The nēnē goose is the State bird of Hawai‘i. A Canada goose is shown in the inset. Photos courtesy of the U. S. Fish and Wildlife Service.

Polynesians were the first settlers of the Hawaiian Islands. The Polynesians brought plants and animals with them to the islands. Other people coming from all over the world also brought plants and animals with them. Today, many of these nonnative plants and animals are causing problems for the native **ecosystems** of Hawai‘i. You will learn about many of these problems in this *Natural Inquirer*.

The island of Hawai‘i is larger than all of the other Hawaiian Islands combined. The youngest of the Hawaiian Islands, Hawai‘i has two active volcanoes. *Kīlauea* volcano is the world’s most active volcano.

Near the coast on the island of Hawai‘i, the temperature is warm all year. In the higher areas near the volcano **summits**, the temperature is cooler. Snow sometimes falls on the summit of *Mauna Kea* volcano. Because it is warm and cool, wet and dry, and coastal and mountainous, the island of Hawai‘i has a wide variety of ecosystems. It is so diverse that no other place on Earth is like it. At least one-half of the ecosystems in Hawai‘i are in danger today from changes

caused by humans. Of the plant and animal species already lost forever in the United States, about 75 percent are from Hawai‘i. Of all plant and animal species in danger of being lost in the United States today, about 25 percent are in Hawai‘i.

Hawaiian citizens today represent a wide variety of races and ethnic backgrounds. Native Hawaiians and other Pacific Islanders make up only about 10 percent of the population. You will learn, however, that Hawaiians have made a commitment to preserve native Hawaiian culture and many of its customs. At the end of each article, you will read about how many of today’s Hawaiians keep traditional Hawaiian culture alive.

Like other early cultures, early Hawaiians felt a special connection to the land. They held the land in deep **reverence** and developed practices to express this reverence and respect. Early Hawaiians understood that although they may be only one individual, they were also a part of the human and natural community. This spiritual connection was often expressed by chanting (*oli*). Chanting was used to express *‘ihi* (respect), *mililani*



Kīlauea volcano caldera. Photo by Babs McDonald.

(praise), *mahalo* (thanksgiving), *aloha* (love), *ʻohana* (family connections and kinship with other life forms), *haʻahaʻa* (humility), and *kupono* (righteousness). Today, many Hawaiians keep the practice of chanting alive, and by doing so acknowledge these values in their lives.

Federated States of Micronesia

The Federated States of Micronesia (FSM) form a nation made up of more than 600 islands. Only 65 of these islands are **inhabited**. The FSM has four states, similar in many ways to the States within the United States. Each state, for example, has its own government. These states are Yap, Chuuk, Pohnpei, and Kosrae. The FSM is located just north of the equator. Its temperature rarely changes throughout the year, with an average temperature of 27 degrees Celsius (°C) (80 degrees Fahrenheit (°F)). Daily highs are about 31°C (88°F) and daily lows are about 25°C (77°F). Rainfall is heaviest in the summer. The FSM may be one of the wettest places on Earth. Some areas of FSM receive about 838 centimeters (330 inches) of rain every year! (On the average, about how much rain do these areas receive every day? How does this compare with the amount of rainfall in your area?)

The total land area of the FSM is not large, totaling only 702 square kilometers (271 square miles, or a little larger than Washington, DC, and the State of Delaware combined). The 607 islands, however, cover about 2,589,000 square kilometers (1,000,000 square miles) of ocean. Formed millions of years ago by volcanoes, the environment of the FSM includes mountains, river valleys, hills, grasslands, and sandy beaches. One of the special environments in the FSM that you will learn about is mangrove forests. These forests are found along the coast where they thrive in salt water.

Like in Hawaiʻi, nonnative (**invasive**) species have become a problem in FSM. Recently, scientists have begun to identify invasive species and suggest what should be done to control or eliminate them.

At least nine languages, including English, are spoken throughout the FSM. Because so many ocean miles separate the four states, each state has a different culture. Although modern in many aspects, the FSM has also maintained its **traditional** ways of life. Farming and fishing are the main occupations of people living in the FSM.

The Pacific Islands may be far away from your community. As you read about Hawaiʻi and the FSM in this *Natural Inquirer*, however, think of how your own community is similar to the Pacific Islands and how it is different.

Glossary

Caldera (kal der ə): A cauldron-like feature created when land collapses following a volcanic eruption.

Ecosystem (ē kō sis təm): A system made up of an ecological community of living things interacting with their environment, especially under natural conditions.

Inhabited (in ha bə təd): Occupied or lived-in.

Invasive (in vā siv): Tending to spread.

Native (nā tiv): Living or growing naturally in a particular region.

Reverence (rev ə rən(ts)s): Honor or respect felt or shown.

Species (spē sēs): A class of individuals having common attributes and designated by a common name.

Summit (sə mət): The highest point.

Traditional (trə di shən nəl): Being established or customary.

Treasure Islands

Hawaiian Kīpuka and the Future of Native Hawaiian Birds

Photo courtesy of David Flaspohler.

Meet the Scientists



▼ **Dr. Christian Giardina**, Ecologist: I like being a scientist because I like understanding how nature works. It is great to have a job studying plants and animals and the forests in which they live. I am an ecologist who works to protect forests. Sometimes I work to restore forests that have been damaged by **invasive species**, human disturbances, or things like drought from climate change. I use information from my research on forests to understand how to make forests more resistant to disturbances. I also learn how to rebuild forest **ecosystems** after they have been damaged.

My favorite experience as a scientist happened when I was doing forest **ecology** research in the country of Belize in Central America. I was walking along a river called the Rio Frio (cold river), which ran through the most



amazing rainforest. Hundreds of species of giant trees grew in this forest. I came upon an enormous cave that the Rio Frio ran through. Amazing plants grew all along the rim of the cave, and it was full of bats. Bats are some of the most incredible creatures in the world. *Photo by Skeeter Zimsky.*

► **Dr. Patrick Hart**, Avian Biologist: I am an ecologist who studies birds on the island of Hawai'i. Hawai'i has some of the most beautiful birds in the world. Many of the **native** bird populations, however, are declining and in danger of **extinction**. I work with other bird ecologists to better understand the causes of this decline. We also work to find ways to protect the remaining birds and even help them increase in numbers. Being a scientist who studies birds is a bit like being a detective. The birds give us clues about why their populations are declining and what we can do to help. Our job is to piece all these clues together into a big picture that we humans can understand. I like this job because it lets me spend time in the forest surrounded by the birds and plants that I love.

One of my favorite experiences recently was flying into a remote rain forest by helicopter to survey birds and plants. Few biologists had ever been to this area. This area was also home to *Pu'u 'O'o*, an active volcano. Our helicopter landed on a field of lava that was a flowing, **molten** river just a week before. Trees along the edge of the flow had been knocked over and burned by the lava and were still smoking. Just steps from the edge of the flow, however, the forest was untouched and beautiful.



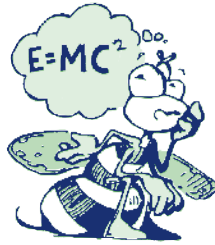
► **Dr. David Flaspohler**, Avian Ecologist: My favorite science experience was realizing that science is about exploration and curiosity. As an ecologist, I get to spend a lot of time watching nature. I observe the behavior of birds and the ways that they interact with their environment. As a scientist, I have the privilege of being paid to explore some of the most interesting and beautiful creatures on the planet.



Thinking About Science

Scientists try to control as many things as possible in a research project. Let's say that a scientist wants to understand how much water a particular type of potted plant needs to grow its healthiest.

The scientist might plant seeds of that plant type in six pots that are made up of the same material, are the same size, and contain the same kind of soil. The pots would be kept in



Glossary words are in **bold** and are defined on page 19. Hawaiian words are in *italics* and their pronunciation is given on page 106.

the same temperature and the same amount of sunlight. The only difference is the amount of water given to the plants. All of these things are known as **variables**. By controlling all the variables except for water, the scientist can be relatively certain that any difference observed in how the plants grew was related to the different amounts of water given to the plants.

In this study, the scientists found a natural environment that was similar in many ways to the six pots. This environment is called a *kīpuka*. A *kīpuka* is an area of forest surrounded on all sides by volcanic lava flows (**figures 1a-c**). This means that a *kīpuka* is like a forested island in a sea of hardened lava.

The main difference between the *kīpuka* in this study was their size in hectares and the **complexity** of their plants and trees, especially their heights. The scientists were interested in discovering how many and what species of birds live in different *kīpuka*. If they found any differences, what do you think might be the reasons?

What kind of scientists did this research?

Avian biologist: This kind of scientist studies the characteristics of birds, including their physical bodies and their behavior.

Avian ecologist: This kind of scientist studies how birds interact with their **habitat**.

Ecologist: This kind of scientist studies the relationship of living things with their living and nonliving environment.



Figure 1a. *Kīpuka* are forested islands in a sea of hardened volcanic lava flow. In the Hawaiian language, “s” is not used to refer to the plural. Photo by Babs McDonald.



Figure 1b. *Kīpuka* have definite boundaries between the forested area and the hardened lava that surrounds them. Photo by Babs McDonald.

Thinking About the Environment

The native forests of Hawai'i have been home to 113 species of birds found only in Hawai'i. When a species is found in only one place and no other, it is said to be **endemic** (ən dəm ik) to that area (**figure 2**). Of the 113 endemic bird species, 71 are **extinct**, and 31 are listed as **endangered species**. Seven native bird species are found in *kīpuka* on the island of Hawai'i. Two of these—the 'io or Hawaiian hawk and the 'Akiapola'au—are endangered species.



Figure 2. If you want to see an *i'iwi*, you will have to visit Hawai'i because that is the only place they are found on Earth. What do you call a species that is found nowhere else? Photo by David Flaspohler.

Native Hawaiian bird populations are under threat from many things. Nonnative birds compete for food and nesting sites. Removing forests for buildings or agriculture reduces the habitat of native birds. A disease called avian malaria has killed many of the native birds living at the low **elevations** on the island of Hawai'i (**figure 3**). Avian malaria is spread by mosquitoes, which cannot live in the colder climate of the middle and higher elevations. The *kīpuka*, which are found at the middle elevations, provide protection from avian malaria for native Hawaiian birds. If nonnative birds are found living in the *kīpuka*, native bird species in Hawai'i may suffer even more through competition for food and nest sites.

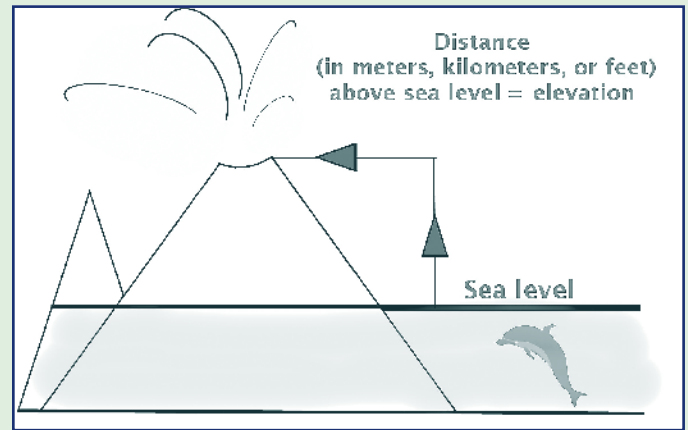


Figure 3. Elevation is a measure of the height of land above sea level.

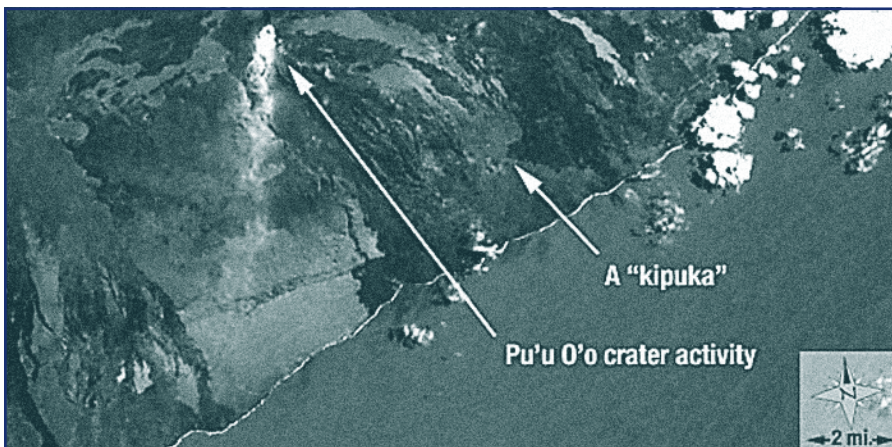


Figure 1c. A *kīpuka* created by a recent Pu'u 'O'o volcanic eruption on Hawai'i illustrates how *kīpuka* are formed. The white shapes on the right are clouds, and the lava is flowing into the ocean. The white area on the left is steam from the volcano. Image courtesy of the National Aeronautics and Space Administration.

Be sure to read,
"Cultural *kīpuka* in
Hawai'i" on page 22.

Introduction

When native wildlife is under threat, scientists want to learn as much as possible about that wildlife's habitat. In particular, some scientists want to know if native wildlife species prefer some habitats. These scientists want to know if nonnative wildlife also live in the preferred habitat. When nonnative wildlife move into the habitat of native species, they threaten the native species even more.

The scientists in this study were interested in learning about birds living in different sized *kīpuka* on the island of Hawai'i (figure 4). *Kīpuka* are like islands of forest surrounded by hardened lava (figure 5). The *kīpuka* studied by the scientists were located on the *Mauna Loa* volcano (figure 6). The *kīpuka* were created during a volcanic eruption in 1855 (figure 7). The *kīpuka*, therefore, have been like forested

islands for more than 150 years. The scientists considered past studies of birds in other forest habitats. Based on what was already known, the scientists **hypothesized** that larger *kīpuka* with taller trees and more complex vegetation would have a greater variety of native and nonnative bird species.



Figure 5. Hardened lava surrounds the *kīpuka*. You can see the edge of a *kīpuka* on the right. Photo by Babs McDonald.

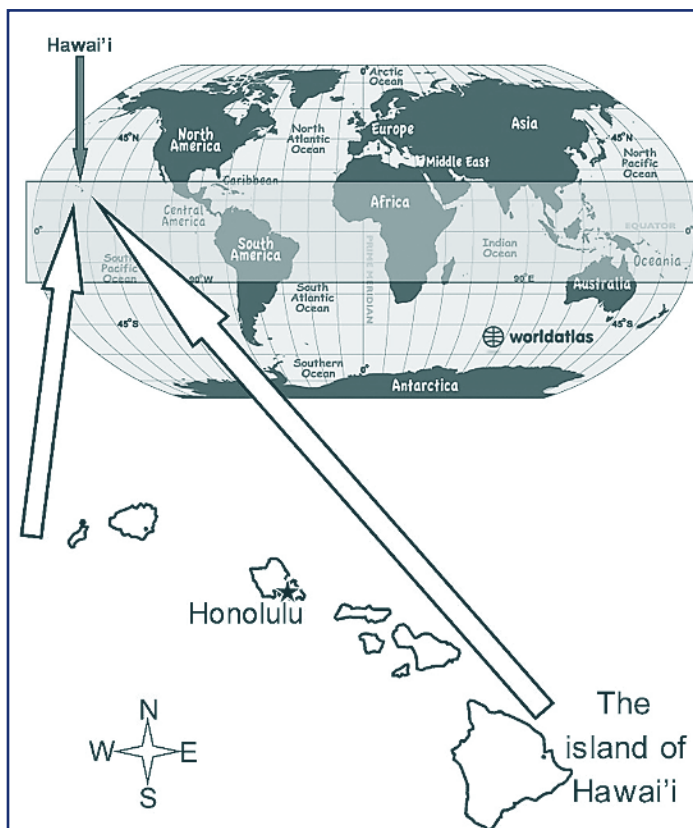


Figure 4. Hawai'i, consisting of a group of islands, is located in the Pacific Ocean. The island of Hawai'i is the largest of the Hawaiian Islands. In 1959, Hawai'i became the 50th State in the United States.



Figure 6. *Mauna Loa* is Earth's largest volcano; it covers about one-half of the island of Hawai'i (See inset). *Mauna Loa* is a shield volcano with gentle slopes. *Mauna Loa* rises almost 4 kilometers (13,000 feet) above sea level. The true height of *Mauna Loa*, when considered from its base on the ocean floor, is about 17 kilometers (56,000 feet)! This height is almost twice that of Mt. Everest. In this photo, *Mauna Loa* is 56 kilometers (about 35 miles) away and is 2.4 kilometers (8,000 feet) higher than the elevation at which this photo was taken. *Mauna Loa* is an active volcano, and its last eruption was in 1984. See http://www.k12.hi.us/~kapunaha/student_projects/volc_blowout/shield_volcano.htm for more information about shield volcanoes. Photo by Babs McDonald. Inset courtesy of the United States Geological Survey (USGS).

A BIG Question:

Why should humans care about endemic and endangered plant and animal species? By the end of this article, be prepared to discuss whether the scientists' recommendation should be followed in Hawai'i.

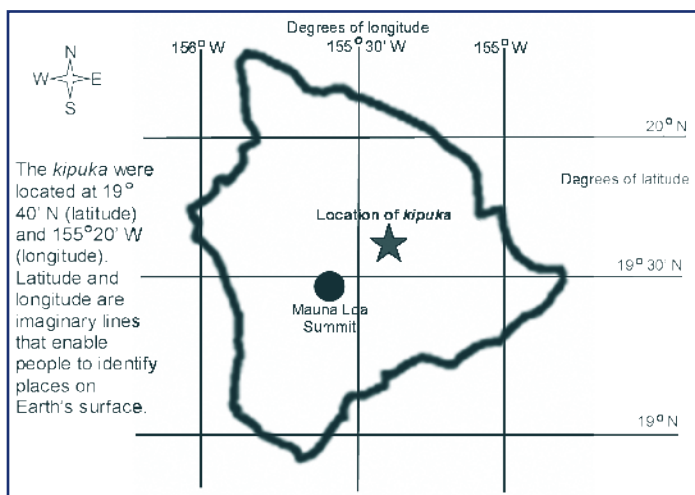


Figure 7. The *kīpuka* are located northeast of the summit caldera of *Mauna Loa* on Hawai'i. A caldera is a cauldron-like feature created when land collapses following a volcanic eruption. A summit caldera is the caldera at the highest point of the volcano. See page 6 for a photo of *Kīlauea* caldera, also on Hawai'i.

Reflection Section



- Why do you think the scientists were interested in learning about the habitat of native and nonnative bird species in Hawai'i? If you need a hint, reread "Thinking About the Environment."
- State the hypothesis in the form of a question.

Scientists state a hypothesis in a particular way. They state a hypothesis as if no relationship will be found between the variables they are studying. This statement is called a null hypothesis. For example, a scientist might hypothesize the amount of water provided to a potted plant has no relationship to its rate of growth. The scientist then tries to prove or disprove the hypothesis. In your own words, state the scientists' hypothesis for this study.

Methods

The scientists studied 18 *kīpuka* ranging in size from 0.1 hectare to 56 hectares. These *kīpuka* were between 1,470 meters and 1,714 meters above sea level. The scientists also studied a large area of forest land that was just less than 1,000 hectares in size. The scientists used this large forested area as a **control**.

Number Crunches

- What was the **range** of the *kīpuka* in acres? Multiply the number of hectares by 2.47 to find out.
- What was the range in elevation of the *kīpuka* in feet? Multiply the number of meters by 3.27 to find out.
- About how far below the summit of *Mauna Loa* were the *kīpuka* located?

The scientists first identified the complexity and height of vegetation in each *kīpuka*. To determine the complexity of the vegetation, the scientists walked into each *kīpuka*. They observed and recorded the types of vegetation found in each *kīpuka* (**figure 8**).



Figure 8. The scientists observed and recorded the types of vegetation and trees found in each *kīpuka*. This *hāpu'u* tree fern is endemic to Hawai'i. Photo by Babs McDonald.

To measure the height of the vegetation, the scientists used a technology called LiDAR. LiDAR stands for Light Detection and Ranging. LiDAR uses beams of light to measure distances. These beams of light are sent to Earth from a satellite or an airplane. For this study, an airplane was used. Each beam of light is reflected off of the Earth's surface and is sent back to the airplane. Scientists know the speed of light and the amount of time each light beam takes to return to the plane. With this information, they use a computer program to calculate the distance between the airplane and the Earth's surface. When the light reaches vegetation such as trees or it reaches the ground, it bounces off of the trees or ground and back to the airplane (**figure 9**). With this information, scientists can calculate the height of trees.

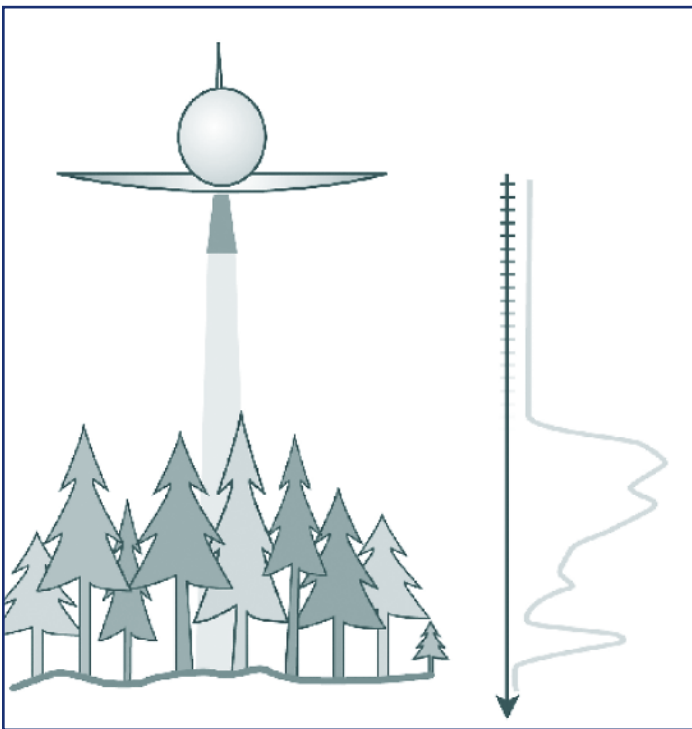


Figure 9. Using LiDAR, scientists can accurately calculate the height of vegetation such as trees.

One of the scientists went into each *kīpuka* to observe and record the species of birds found living in that *kīpuka*. The scientist visited each *kīpuka* twice in the winter and twice in the summer. He did all of his observations between 30 minutes after sunrise and 11 a.m. Each observation lasted for 30 minutes. Half of the time the scientist observed in early morning, and the other half of the time he observed in late morning. Each bird species has a unique song that the scientist learned. When he heard or saw a bird, the scientist recorded its species and the *kīpuka* in which he found it.

Number Crunches

🍁 If it is 11:00 a.m. in Hawai'i, what time is it where you live? Hawai'i is 5 to 6 hours behind the United States Eastern Time. The amount of time depends on whether the Eastern Time Zone is on Daylight Savings (6 hours behind) or Standard Time (5 hours behind). Hawai'i is 10 hours behind Coordinated Universal Time (UTC). UTC is similar to Greenwich Mean Time. (Hint: Hawai'i does not observe United States Daylight Savings Time and is in the Hawai'i-Aleutian Time Zone.) What time is it in Hawai'i right now?

Reflection Section

- 🍁 How did the large area of forest serve as a control?
- 🍁 Why did the scientists record the type of vegetation and trees found in each *kīpuka*?



Findings

The vegetation and tree species were similar in all of the *kīpuka* studied. The exception to these similarities was the largest *kīpuka*, in which the native *koa* tree was also found.

The highest number of different bird species that was possible to observe was 14. The scientists found 10 species living in the large nearby forest. As they expected, the scientists found that the smaller the *kīpuka* in hectares, the fewer number of bird species were found living there (**table 1**). The number and type of species did not vary between summer and winter.

Five of the six most frequently found bird species were native species. The nectar-feeding *‘apapane* was the most commonly found species (**figure 10**). It was found in every *kīpuka* studied as well as in the large forest.

The *i‘iwi* (**figures 11a and 11b**) and *ōma‘o* (**figure 12**) were two other native species commonly found in the *kīpuka*.

Table 1. The larger the *kīpuka* in hectares, the larger the number of birds species that were found.

<i>Kīpuka</i> number	Area in hectares	Total number of native and nonnative bird species found in the <i>kīpuka</i>	Total number of nonnative bird species found in the <i>kīpuka</i>
4	0.07	2	0
1	0.07	3	0
11	0.09	2	1
13	0.13	3	0
2	0.13	4	1
17	0.17	2	0
12	0.19	3	0
9	0.57	5	1
14	0.59	3	0
6	1.22	5	1
10	1.70	5	1
3	2.18	6	0
15	3.18	6	0
5	9.28	5	0
7	18.54	6	1
8	35.55	7	1
16	38.64	8	2
18	55.7	9	3
Large forest	About 1,000	10	4



Figure 10. The *‘apapane* uses its curved beak to drink nectar from flowers. The *‘apapane* is endemic to Hawai‘i. Photo by David Flaspohler.

The endangered 'io (Hawaiian hawk) was found only in the largest *kīpuka* and in the large area of forest (**figure 13**). Of the 11 species observed in the *kīpuka* and the large forest, 5 were

nonnative species. The larger the *kīpuka*, the more nonnative species were observed.

The scientists also found that the *kīpuka* with the tallest trees had the greatest number of bird species (**figure 14**).



Figure 11a. An 'apapane and an i'iwi. What are the similarities and differences between the 'apapane and the i'iwi? Which of these birds is the i'iwi? How do you know? Photo by David Flaspohler.



Figure 11b. What kind of food do you think the i'iwi eats? How do you know? Photo by Nolan Lancaster.



Figure 12. After each bird was caught, a band was placed on its leg, and then it was released. Here, Nolan Lancaster and Elizabeth Ames are releasing an ōma'o. The bands were placed on the legs in a unique color combination that enabled the scientists to individually identify each bird. Photo by Jessie Knowlton.



Figure 13. The 'io needs large areas of forest. Photo by Dr. J. B. Friday.

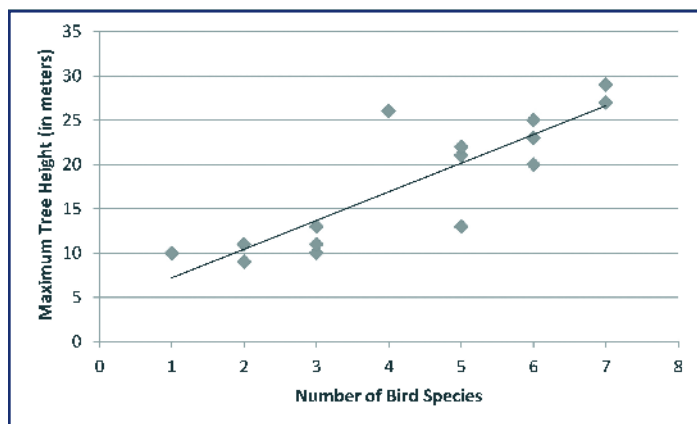


Figure 14. The number of bird species found in the *kīpuka* was closely related to the maximum height of the trees. As you can see in this scatter plot, as the maximum height of the trees increased, the number of bird species also increased. The line in the scatter plot is placed to indicate the general relationship between maximum tree height and number of bird species.

Reflection Section



- Based on the findings, do you think the 'apapane is likely to be one of the endangered bird species? Why or why not?
- Read the next-to-the-last sentence in "Findings" and examine table 1. What can you say about the *kīpuka* and the future of native bird species?
- Looking over table 1 and figure 14, what can you say about the height of trees in different size *kīpuka*?

Discussion

This study is unusual because the *kīpuka* have been like forested islands for more than 150 years. This number of years is a long time to be isolated from other areas of forest. When *Mauna Loa* erupted in 1855, the *kīpuka* were created at the same time, and the hardened lava has discouraged tree growth around the *kīpuka*. Without new growth, the *kīpuka* have remained isolated from one another. Because the *kīpuka* are surrounded by hardened lava, they have not been disturbed much by human activities. The *kīpuka*, therefore, are a good place to study how different species of birds come into and live in an isolated forest patch.

One of the most interesting findings of this study is that nonnative bird species do not appear to live in *kīpuka* under about 10 hectares in size. Native bird species live in small-sized *kīpuka* without danger of having their habitat

taken over by nonnative birds. These small forested islands, therefore, may act as a **refuge** for some native bird species.

The *kīpuka* are located at the middle elevations. This level of elevation is above the range of mosquitoes that carry and spread avian malaria to birds with their bites. As Earth's climate changes and the average temperature rises, malaria-carrying mosquitoes may one day be able to live in the middle elevations. If this change happens, native bird species will need a new habitat to survive. This habitat must be beyond the range of mosquitoes. The scientists recommended restoring small areas of native forest at higher elevations. Because the number of native bird species living in *kīpuka* is also related to the height of trees, it is important to begin native forest **restoration** at higher elevations early to allow trees to grow tall.

BIG Questions:

Why should humans care about endemic and endangered species?

Should the scientists' recommendation be followed? Why?

Reflection Section



- ❦ What is one advantage of restoring small forest patches?
- ❦ What is one disadvantage of restoring only small forest patches? (Hint: Think about the 'io or Hawaiian hawk.)
- ❦ Why might it be important to begin now to restore patches of native forest at higher elevations?

Adapted from Flaspohler, D.J.; Giardina, C.P.; Asner, G.P.; Hart, P.; Price, J.; Lyons, C.K.; Castaneda, X. 2010. Long-term effects of fragmentation and fragment properties on bird species richness in Hawaiian forests. *Biological Conservation*. 143: 280–288. [http://www.fs.fed.us/psw/publications/giardina/psw_2010_giardina\(flaspohler\)003.pdf](http://www.fs.fed.us/psw/publications/giardina/psw_2010_giardina(flaspohler)003.pdf).

This research received support from the National Science Foundation, the Forest Service, and a Michigan Technological University Faculty Development Grant.

Glossary

Alien (ā lē ən): Differing in nature or character typically to the point of incompatibility.

Avian (āv ē ən): Having to do with birds.

Complexity (kām plek sə tē): Characterized by having complicated or related parts.

Control (kən trōl): In science, a control is a situation used for comparison. Usually, it is found naturally.

Ecology (ē kā lə jē): The study of the relationship between living things with each other and with the nonliving environment.

Ecosystem (ē kō sis təm): A system made up of an ecological community of living things interacting with their environment, especially under natural conditions.

Elevation (e lə vā shən): The height above the level of the sea.

Endangered species (en dān jərd spē sēs): A species threatened with extinction.

Extinct (ik stɪŋ(k)t): No longer living.

Extinction (ik stɪŋ(k) shən): The state of being extinct; no longer existing.

Habitat (hab ə tat): The place or environment where a plant or animal naturally or normally lives and grows.

Hypothesize (hī pā thə sīz): To make an assumption to test its logical consequences.

Invasive species (in vā sɪv spē sēs): A plant or animal species not native to an area and with the potential to harm the native environment.

Molten (mōl tən): Liquefied by heat.

Native (nā tiv): Living or growing naturally in a particular region.

Range (rāŋj): The region throughout which a kind of organism or ecological community naturally lives or occurs.

Refuge (ref yūj): A place that provides shelter or protection.

Restoration (res tə rā shən): The act of bringing back to an earlier condition.

Species (spē sēs): A class of individuals having common attributes and designated by a common name.

Variable (ver ē ə bəl): Something that is able or apt to vary.

Accented syllables are in **bold**. Definitions and marks are from <http://www.merriam-webster.com>.

FACTivity



Time Needed

One to two class periods (one for homework or background research, one period for in-class FACTivity).

Materials

- Copy of charts on pages 20 and 21.
- Treasure Islands article.
- Access to Internet, media center, or encyclopedias.
- Pencil.

The question you will answer in this FACTivity is: What are the similarities and differences between isolated environments of various sizes?

As you learned in this article, a *kīpuka* is a forested island in a “sea” of hardened lava. The lava has isolated each *kīpuka* so that the plants and animals that live there have had a

measure of protection from invasive species. The Hawaiian Islands are similar in some ways to *kīpuka*. They are forested volcanic islands in the middle of the Pacific Ocean. The Hawaiian Islands are the most isolated islands on Earth. This isolation had, in the years before humans populated the islands, protected Hawai‘i from invasive species.

For this FACTivity, consider the Hawaiian Islands as a type of *kīpuka*. The volcanic island *kīpuka*, however, are much larger than the forested islands created by lava. You will compare the Hawaiian Islands with the *kīpuka* studied in this research. Consider the Hawaiian Islands in two ways: all islands as a *kīpuka* and each island as a *kīpuka*.

The method you will use to answer the question is:

You will work in small groups. Using the chart below, compare the Hawaiian Islands with the *kīpuka* studied in this research. Research may be done at the media center or at home. Think of another isolated environment to compare. If possible, this isolated environment should be close to home or school. This other environment could be very small or quite large, such as an island in a lake or a median strip in the

center of a highway. After completing the first chart, summarize the similarities and differences in the second chart. Finally, write a sentence or a paragraph about all isolated environments.

Your teacher will hold a class discussion about the class findings. Discuss what makes these isolated environments similar. What makes them different? What can be said about all isolated environments?

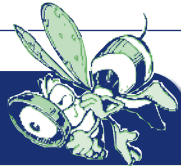
	Forest <i>kīpuka</i>	Each Hawaiian island as a separate <i>kīpuka</i>	Hawaiian Islands as one <i>kīpuka</i>	(Optional) Other isolated environment (describe):
Size				
Animals and Plants				
What isolates the <i>kīpuka</i> ?				
General description				

Similarities between *kīpuka*

Differences between *kīpuka*

All isolated environments...

Extension



After reading “Cultural *kīpuka* in Hawai‘i” on the following page, compare the *Waipi‘o* Valley as a cultural *kīpuka* with the forested *kīpuka* described in this article. You may use the chart on the previous page as a guide. After you have completed the comparison, your teacher will hold a class discussion about the similarities and differences between forested *kīpuka* and cultural *kīpuka*. Then read your conclusion about “All isolated environments.” Is what you concluded true for cultural *kīpuka* as well? If so, why do you think that is so? If not, why not?

Math FACtivity

Create a bar chart for table 1. Place *kīpuka* area on the Y-axis and the other three columns on the X-axis. Note that you will create two columns for each numbered *kīpuka*. Your teacher will hold a class discussion about whether the table or the bar chart is easier to understand. Does everyone in your class agree? Why do you think that is the case? Why is one easier to understand than the other? What does this discussion tell you about how scientists (and you) should present data?



Cultural Kipuka in Hawai‘i

You have just learned about the *kipuka* in Hawai‘i. *Kipuka* are forested islands in the middle of a sea of hardened lava. Because these *kipuka* are isolated environments, they have kept their native plant and animal species over time. At the same



Figure 15. Dr. Davianna Pōmaika‘i McGregor is a social scientist who studies Hawaiian culture.

time, other forested areas in Hawai‘i have experienced invasions from **alien** plant and animal species. In 2007, a native Hawaiian social scientist who studies the cultural history of Hawai‘i considered an interesting comparison. Just as

Hawai‘i has forested *kipuka* she wrote, it also has cultural *kipuka* (**figure 15**).

The natural environment of the island of Hawai‘i is steep and rugged in many places. Over the centuries, native Hawaiians settled in isolated areas of Hawai‘i. These places were isolated for different reasons. For example, steep mountains and cliffs might have isolated them. When Caucasians and Asians came to Hawai‘i, they usually went to the places to which they could travel easily or that were good for large-scale agriculture.

Waipi‘o Valley was particularly isolated (**figures 16–18**). Even today, *Waipi‘o Valley* is difficult to visit. A four-wheel drive vehicle is needed to go into the valley. *Waipi‘o Valley* is known as the valley of kings. It is considered a sacred place, or *wahi pana*.

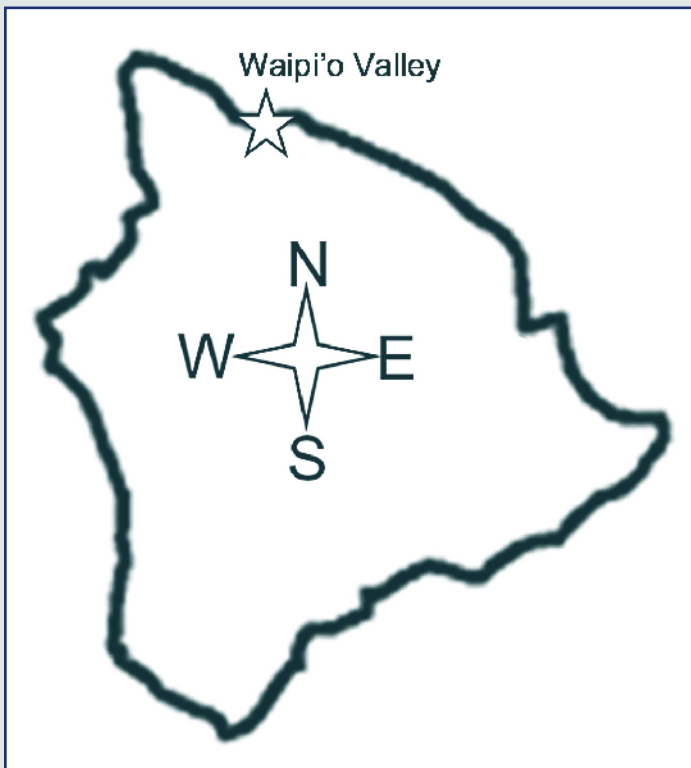


Figure 16. *Waipi‘o Valley* is located on the north-northeastern coast of Hawai‘i.



Figure 17. *Waipi‘o Valley* is known for its beautiful landscapes and steep mountains. Photo by Richard MacKenzie.



Figure 18. *Waipi'o Valley* is difficult to visit, even today. Photo by Richard MacKenzie.

Because of the isolation of *Waipi'o Valley*, its residents maintained Hawaiian customs and lifestyle to the present day. As had been done by early Hawaiians, native Hawaiians still cultivate taro and traditional varieties of banana, sweet potato, and sugar cane. Taro is a root crop that grows in wet soils and is a main food source for about 10 percent of the world's population. Fishing is still a large part of *Waipi'o* culture, though modern tools are often used. Trees, fruits, nuts, and plants for eating and for medicine are found in the valley. Because the valley is rich in natural resources, its residents felt and still feel little need to buy products beyond what is necessary. In today's cultural *kīpuka*, only things like flour, salt, soap, batteries, and kerosene are brought in from outside the valley.

“Treasure Islands” refers to the title of a famous young adult adventure novel, *Treasure Island*, by Scots author Robert Louis Stevenson. *Treasure Island* is a story about pirates and buried gold. It was published in 1883.

Just as forested *kīpuka* have protected many native Hawaiian plant and animal species, cultural *kīpuka*, such as *Waipi'o Valley*, have preserved many traditional Hawaiian perspectives and practices. Dr. McGregor studied *Waipi'o Valley* as a cultural *kīpuka*. Dr. McGregor observed, “*Kua'aina* are the native Hawaiians who remained in the rural communities of our islands, took care of the *kūpuna* or elders, continued to speak Hawaiian, bent their backs and worked and sweated in the taro patches and sweet potato fields, and held that which is precious and sacred in their care” (2007, p. 4).

Adapted from McGregor, D.P. 1995. *Waipi'o Valley*, a cultural *kīpuka* in early 20th century Hawai'i. *Journal of Pacific History*. 30(2): 194–209 and McGregor, D.P. 2007. *Nā Kua'aina: Living Hawaiian culture*. Honolulu: University of Hawai'i Press.

Additional Web Resources

Hawai'i Volcanoes National Park:
<http://www.nps.gov/havo/>

U.S. Geological Survey *kīpuka* page:
<http://volcanoes.usgs.gov/images/pglossary/kipuka.php/>

U.S. Geological Survey *Mauna Loa* page:
<http://hvo.wr.usgs.gov/maunaloa/>

U.S. Geological Survey Hawai'i volcanoes page:
<http://hvo.wr.usgs.gov/>

A history of Hawaiian native birds (The National Zoo/Smithsonian Institution):
<http://nationalzoo.si.edu/publications/zoogoer/1995/1/hawaiisforestbirds.cfm/>

University of California—Los Angeles Botanical Garden taro page:
<http://www.botgard.ucla.edu/html/botanytextbooks/economicbotany/colocasia/index.html>

Adaptation lesson plan:
<http://www.uhh.hawaii.edu/affiliates/prism/documents/unitintroduction.pdf/>

***Waipi'o Valley* (Wikipedia):**
http://en.wikipedia.org/wiki/waipio_valley

***Waipi'o Valley* history:**
http://gohawaii.about.com/cs/bigislandland/a/waipio_valley.htm

National Education Standards

National Science Education Standard	Where and How the Standard Is Addressed
Abilities Necessary To Do Scientific Inquiry	Thinking About Science: The control of variables, isolating the reasons for differences in the number of bird species. Introduction Reflection Section: State the research question. Methods: Technology, observation, recording. Findings: Bird banding. Findings Reflection Section: Drawing conclusions from data.
Understanding About Scientific Inquiry	Thinking About Science: The importance of controlling variables. Introduction Reflection Section: Hypotheses and research questions. Methods: Observation protocol. Methods Reflection Section: Understanding the use of a control, understanding the importance of recording observations. Figure 12: Ethical care of wildlife. Discussion Reflection Section: Implications and further study (both questions).
Structure and Function in Living Systems	Figure 13: Number of bird species and tree height. Discussion: The creation and structure of <i>kīpuka</i> , number of native bird species and <i>kīpuka</i> size. Discussion Reflection Section: Growth and development of trees.
Regulation and Behavior	Introduction: Preferred habitat. Introduction Reflection Section: Relationship between native and nonnative species. Discussion Reflection Section: Native species habitat preference, exclusion of nonnative species by habitat size.
Populations and Ecosystems	Thinking About the Environment: Endemic and endangered species. Introduction: Relationship between native and nonnative species, hypothesis regarding habitat size, tree height, and number of species. Figure 13: Relationship between tree height and number of species. Discussion: Relationship of bird species and mosquitoes.
Diversity and Adaptation of Organisms	Thinking About the Environment: Endemic and endangered species. Introduction: Invasion of species into native habitat. Figure 8: Endemic plant species. Figures 11a and 11b: Adaptations of nectarvores. Discussion: Adaptation to a changing climate.

Structure of Earth System	Thinking About Science: <i>Kīpuka</i> . Introduction: Creation of <i>kīpuka</i> , figures 6 and 7: Volcanoes.
Natural Hazards	Thinking About the Environment: Mosquitoes and avian malaria. Introduction and Introduction Reflection Section: Invasive species.
Science and Technology in Society	Methods: Use of LiDAR.
Understandings About Science and Technology	Methods: Use of LiDAR, figure 9: LiDAR
Science as a Human Endeavor	Meet the Scientists. Thinking About Science, Introduction, and Introduction Reflection Section: What the scientists were interested in studying.
Nature of Science	Thinking About Science: The use of controls. Introduction: The applied nature of science (solving a problem). Discussion: Implications and the application of science to solve problems.

National Curriculum Standard for Social Studies	Where and How the Standard Is Addressed
Culture	Cultural <i>Kīpuka</i> in Hawai'i: Isolation of culture and its implications.
Time, Continuity, and Change	Cultural <i>Kīpuka</i> in Hawai'i: Changes in culture over time.
People, Places, and Environments	The BIG Question: Informal decisionmaking regarding human-environment relationships, consequences of human interaction with the environment. Discussion: Consequences of human interaction with the environment. FACTivity: Understanding spatial perspectives.



Koa Constrictors

Photo courtesy of Paul Scowcroft.

***Studying Things That Slow the
Growth of Koa Crop Trees***

Meet the Scientists



◀ **Mr. Paul Scowcroft**, Research Forester: My favorite science experience was discovering why hanging a sheet of shade cloth on the east side of native *ohia* tree **seedlings** protected them from frost damage. At 6,500 feet **elevation**, where forests have been turned into cattle pasture, temperatures can easily fall below

freezing. Shade cloth is a piece of cloth that lets some sunlight through but also provides some shade.

We wondered if the shade cloth caused the leaves to warm slowly in the morning. This slow warming would be similar to treating frostbite by slowly warming the fingers. We attached electrical wires to the underside of leaves. These wires enabled us to record the leaves' temperature over time. Some of the leaves were fully exposed to the sky. Some were shielded from the morning sun by shade cloth hung on the east side of the seedling. Others were located within a forest of 5-year-old *koa* trees. You will learn more about *koa* trees in this article.

We found that exposed seedlings experienced lower temperatures for a longer time than shade cloth-shielded or *koa*-protected seedlings. The shade cloth blocked part of the night sky and prevented heat loss into space. The *koa* trees blocked even more of the sky. In both cases, the results were warmer leaves. Even though the temperature difference was only 2 to 3 degrees, it reduced frost damage. Under *koa* trees, heat loss was so low that *ohia* seedlings showed almost no damage and kept growing throughout the winter. From this experiment, we learned that after ice crystals puncture the cell walls of leaves, the cells die. It doesn't matter how slowly frozen leaves are warmed! Photo by Dr. J.B. Friday.

Glossary words are in **bold** and are defined on page 36. Hawaiian words are in *italics* and their pronunciation is given on page 106.



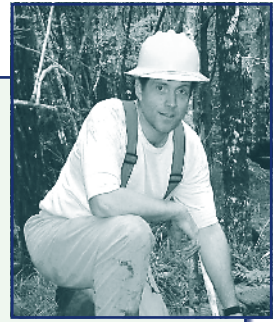
◀ **Dr. Travis Idol**, Forest Ecologist: My favorite science experience was measuring the growth of roots into mesh bags filled with soil. The bags were placed in holes in the ground in forests of different ages. That way, we could tell how fast the roots

were growing. That would tell us how much energy and **biomass** the trees were sending belowground where it is not normally visible. The youngest forests (only 5 years old) had the fastest root growth but also the most rapid root death. These facts make sense because young trees have to grow roots, shoots, and leaves quickly to compete with their neighbors. After the forest ages, the fewer but bigger trees have well-established root systems and leaf canopies, and thus don't have to compete as intensely.

Photo by Dr. J.B. Friday.



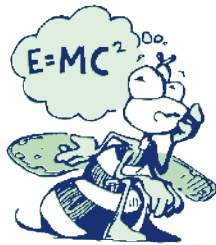
◀ **Dr. Dean Meason**, Forest Scientist: My favorite science experience was working in the soil in the native forests of Hawai'i. Soils can be wet and gooey or light and fluffy. Some soils are rich with **organic** matter, while other soils are rocky. Soils provide water, **nutrients**, and support to trees. Without the right soil the trees will die. Soil is very different in Hawai'i. It all comes from volcanic eruptions. In Hawai'i, you can see lava pouring out of *Pu'u 'O'o* into the sea. Walking up into the mountains you can see hard lava slowly turning into rich volcanic soil that plants can thrive in.



Be sure to read,
“Canoeing and
Surfing in An-
cient Hawai‘i”
on page 38.

Thinking About Science

How do scientists choose what to study? Scientists choose to study things for many reasons. Usually, scientists begin their career studying a topic in which they are interested. Sometimes, they first learned about their favorite topic when they were young. Something about the topic made them curious and they wanted to learn more. (What topic have you found out about that makes you curious to learn more?) When scientists do their research, their attention is on their topic of interest. The specific research questions, however, may be influenced by society. When a social problem is identified in their topic of interest, scientists help solve the problem.



In this research, scientists studied a native tree **species** in Hawai‘i. Many trees of this species were cut down about 100 years ago. Now, however, demand for wood from these trees is rising. People want to be able to use this tree to create wood products. The scientists in this study were already interested in native Hawaiian trees. They decided to help solve the problem by focusing their interest, experience, and research on this particular native tree species.

Thinking About the Environment



The *koa* (*Acacia koa*) tree is endemic to Hawai‘i. It is native only in Hawai‘i. Young *koa* trees grow fern-like leaves (**figure 1**). As *koa* trees grow older, sickle-shaped leaf stems that function like leaves replace the fern-like leaves (**figure 2**). *Koa* trees are found all over the Hawaiian Islands (**figure 3**).



Figure 1. Young *koa* trees have true leaves. These leaves are fern-like in appearance. Photo by Dr. J.B. Friday.



Figure 2. As *koa* trees get older, leaf stems that function like leaves replace the fern-like leaves. Photo by Dr. J.B. Friday.

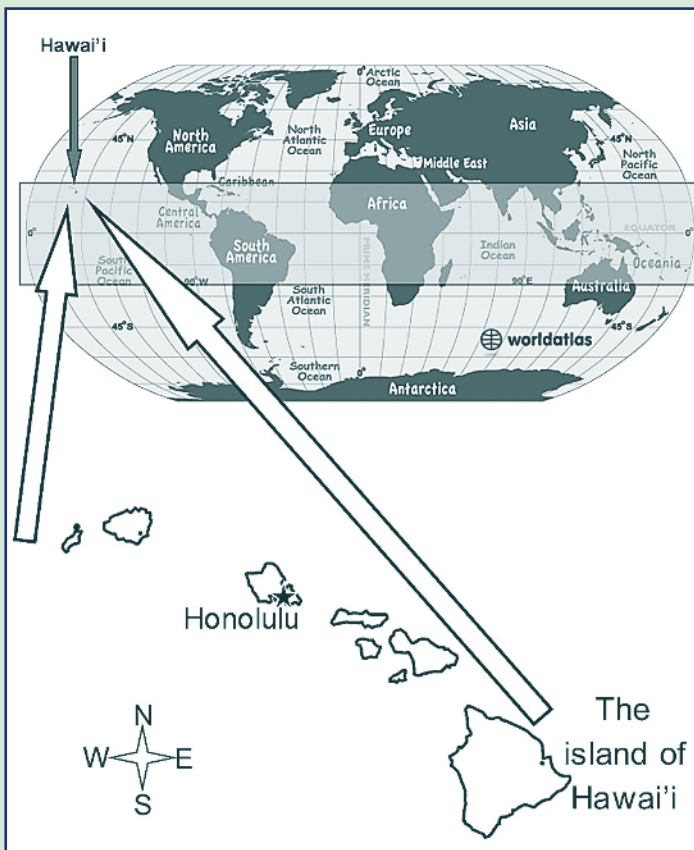


Figure 3. The Hawaiian Islands are located in the Pacific Ocean. In 1959, Hawai'i became the 50th State in the United States.

Koa trees are special because they provide wood for furniture, cabinets, surfboards, body boards, canoes, ukuleles, and guitars (**figure 4**). They also provide **habitat** for **endangered** native bird species. *Koa* trees are culturally important as well. Early Hawaiians built dugout canoes out of the trunk of this tree. Many *koa* trees were cut down in the late 1800s and early 1900s to provide land for agriculture and cattle. In recent years, the demand for the wood from this tree has become larger than the **sustainable supply**. There is now a need to grow more *koa* trees that can be used for wood products. It is also important to protect *koa* trees so that native birds have a place to live now and into the future.



Figure 4. *Koa* wood guitars are known for producing rich tones. These tones get richer as the guitar is played over time. In this photo, Adam Allen is playing an acoustic *koa* wood guitar at Musician's Warehouse, Bogart, Georgia. Country star Taylor Swift plays a variety of acoustic *koa* wood guitars. See <http://taylorswiftkoawoodguitar.com/?p=108>. Photo by Babs McDonald.

Introduction

Koa is one of the most valued of **tropical** woods. A particular type of *koa* tree, called *Acacia koa*, is found in the Hawaiian Islands. The wood from this tree is used to create furniture, cabinets, carved bowls, canoes, surfboards, body boards, ukuleles, and guitars (**see figure 4**). Unfortunately, the future demand for *koa* wood will not be met unless better ways are found to grow *koa* crop trees today. Crop trees are trees with straight trunks and few side branches (**figure 5**). These trunks are best for creating lumber (**figure 6**).



Figure 5. *Koa* crop trees have straight trunks. Photo by Paul Scowcroft.

Although landowners know how to start *koa* trees from seed, young *koa* trees face three obstacles as they grow into crop trees. The first is competition from *koa* trees that do not have straight trunks. The second is competition from nonnative grasses growing under the trees. The third obstacle for *koa* crop trees is growing in soils that lack the necessary nutrients for healthy growth. Because many new *koa* forests are growing on land that was once used for cattle or agriculture, the soil is often low in necessary nutrients.

The scientists in this study were interested in studying these three obstacles for *koa* crop trees. They wanted to measure the growth of *koa* crop trees over a 3-year period following special treatments. Specifically, the scientists wanted to know how *koa* crop trees would respond to each of the following treatments: (1) removing nearby noncrop *koa* trees; (2) killing nonnative grasses with an **herbicide**; and (3) using an herbicide to kill nonnative grasses and adding the fertilizer phosphorus (P) to the soil.



Figure 6. Lumber is cut from *koa* crop trees. Photo by Dr. J.B. Friday.

Why is phosphorus important to *koa* trees?

Phosphorus is one of the three most essential minerals for all plants, including *koa* trees. The other essential minerals are nitrogen and potassium. Phosphorus is necessary for photosynthesis. It helps *koa* trees withstand stress, promotes growth of leaves and roots, and is involved with the manufacture of sugars and starches. If phosphorus is not widely available, *koa* trees may grow more slowly.

Reflection Section

- ❖ Explain in your own words why crop trees are needed for products such as surfboards, body boards, furniture, and guitars.
- ❖ Why did the scientists want to study the three obstacles to *koa* crop tree growth?
- ❖ Look at figure 5. Do you see any noncrop *koa* trees in the photo? How do you know?



Methods

The scientists studied *koa* trees on the northeastern slope of *Mauna Loa* volcano (**figure 7**). The scientists studied an area covering 12 hectares. The trees had been cut down in the 1960s, and the area was used to graze cattle. Although *koa* trees still grew in the pasture, there were few trees compared with the original forest. The disturbance caused by cutting the trees down and having cattle graze allowed nonnative grasses to grow

on the ground. Underground, **dormant** *koa* seeds lay buried. These dormant *koa* seeds have a hard protective coating. Over time soil acids, bacteria, and fungi break down this protective coat, allowing water and oxygen to get inside the seed (**figure 8**). Still, the soil must be disturbed in some way for the seeds to germinate. In 1978, a bulldozer was used to disturb the soil. Soon after, the seeds **germinated**, and young *koa* trees began to grow.

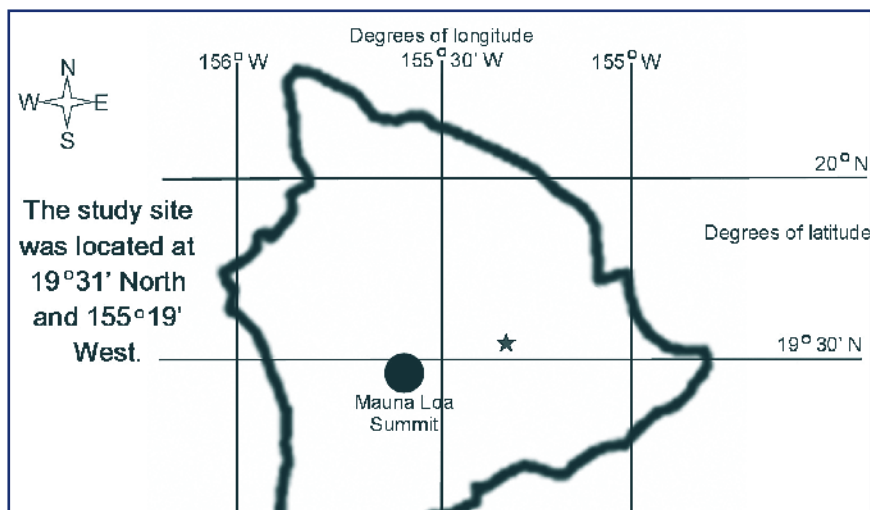


Figure 7. The location of the study site on the island of Hawai'i. For more information about *Mauna Loa* volcano, see figure 6 in the article, "Treasure Islands," in this journal.



Figure 8. *Koa* seeds have a hard protective coating. Photo by Dr. J.B. Friday.

Number Crunches

 How many acres large was the study area? Multiply the number of hectares by 2.47 to find out.

In 2001, the scientists identified eight areas to study within the 12 hectares. In four of the areas, noncrop *koa* trees growing close to crop trees were killed (**figures 9 and 10**). This is called “thinning.” In the other four, noncrop *koa* trees were left as a control. A control is used as a comparison in scientific studies. Each of

these eight areas was 60 meters long on a side. Within each area, the scientists marked four smaller areas. In three of the smaller areas, the scientists applied one of the three treatments, leaving the fourth smaller area untreated (**figures 11 and 12**).

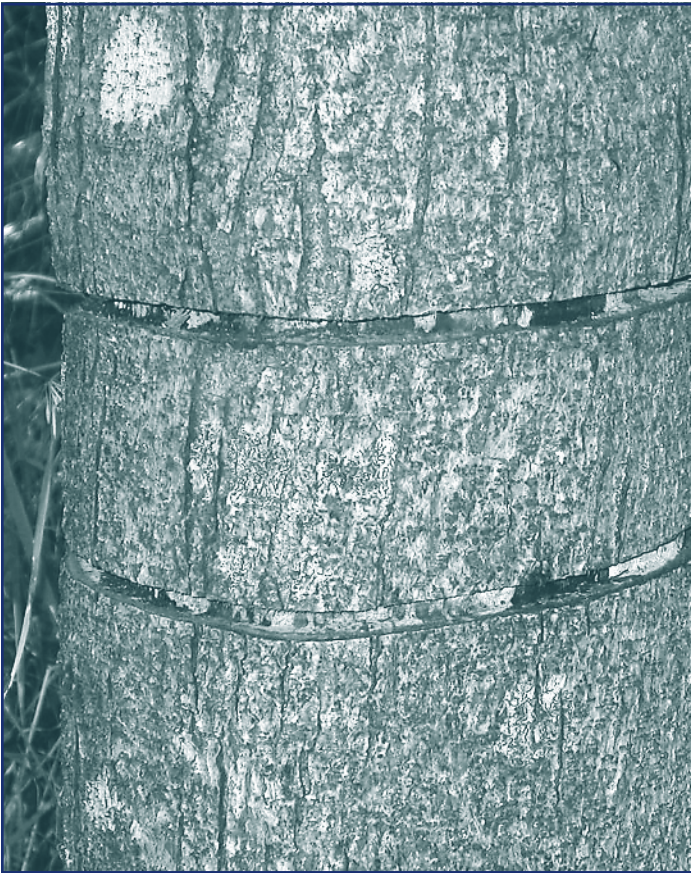


Figure 9. To thin the areas, noncrop *koa* trees growing close to crop trees were killed by girdling. Girdling is a method of cutting around the outer part of the trunk. This cutting stops the flow of sugar-rich fluids down the tree, killing the roots and, gradually, killing the tree. By gradually killing the tree, insects and other animals could still use the tree as habitat. Photo by Paul Scowcroft.



Figure 10. Two noncrop *koa* trees killed by girdling. Photo by Paul Scowcroft.

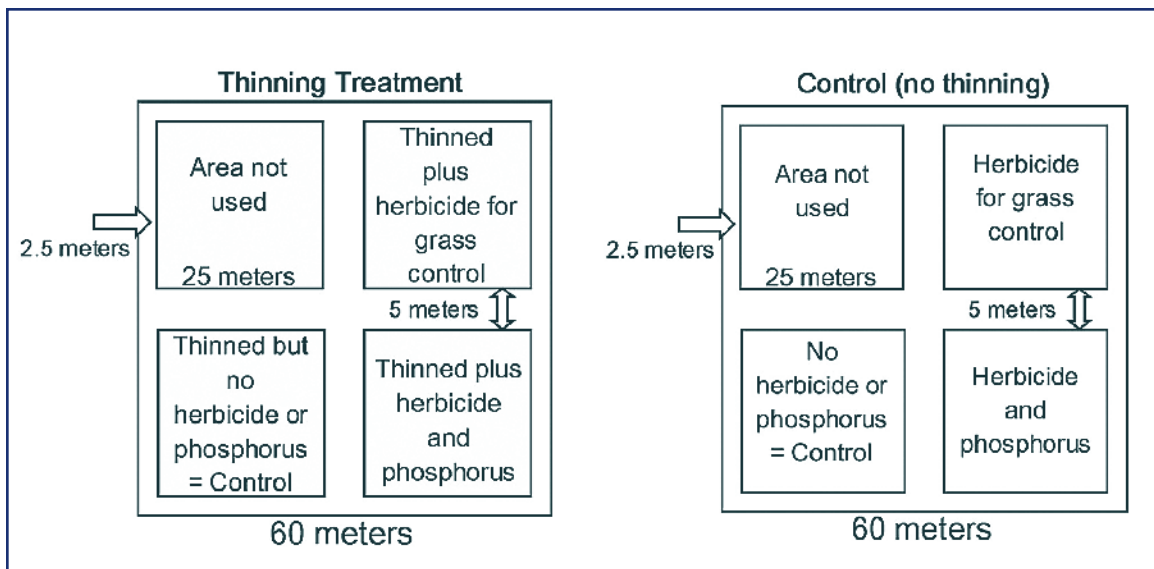


Figure 11. Scientists studied eight areas. Each of these eight areas contained four smaller areas. Only three of the four smaller areas were treated.



Figure 12. Scientists treated the nonnative grasses in this area with herbicide. Photo by Paul Scowcroft.

Number Crunches



How old were the *koa* trees in 2001? How old would they be today?

What is DBH?

DBH stands for diameter at breast height. In the United States, this distance is 1.4 meters from the ground. This method is a standard way to measure the size of trees (**figure 13**). When the tree is growing on a hill, DBH is measured on the uphill side of the tree.



Figure 13. The scientists measured the DBH of every *koa* crop tree in the eight areas. Photo by Paul Scowcroft.

The scientists identified all potential crop trees. In 2001 and 2002, they measured the diameter at breast height (DBH) of every crop tree. They thinned the noncrop *koa* trees in four of the eight areas. Then they applied the herbicide and phosphorus treatments. In the summers of 2003, 2004, and 2005, the scientists once again measured the DBH of all crop trees.

Number Crunches

- How many feet above the ground is DBH? Multiply 1.4 meters by 3.28 to find out.
- How many feet on each side was the study area?

Reflection Section

- Explain in your own words why scientists use a control in which no treatment is applied.
- Why did the scientists measure the DBH of the *koa* crop trees before and after the treatments?



Findings

By the end of the second year, 75 percent of the girdled *koa* trees had died. By the third year, all the girdled trees were dead. The trunks of *koa* crop trees growing in the thinned areas and without other treatments did not grow much larger. In thinned areas with herbicide to control nonnative grasses, the trunk sizes increased by 70 percent. The scientists could not say with confidence, however, that the growth was related to the addition of herbicide. Although a 70-percent increase in size seems high, it was not enough to be sure that the growth was

caused by the herbicide treatment. Scientists always err on the side of caution. When they cannot be relatively certain, scientists say that the observed difference in growth is not significant.

In the thinned areas where herbicide was used along with the application of phosphorus, the *koa* crop tree trunks more than doubled in DBH. In this case the scientists were confident that the combination of thinning, herbicide, and phosphorus contributed to the faster growth. The scientists called the doubling a significant difference in observed growth.

What makes an observed change significant?

When scientists do experiments or make observations, they realize that they usually will not be able to make a conclusion for sure. In most instances, the best they can do is conclude that an observed change is not due to a chance occurrence. Depending on the number of observations and the strength of the observed change, scientists might call an observed change significant. When scientists are fairly certain that the observed change was not caused by a chance occurrence, it

is considered a significant change. Scientists do not just decide for themselves whether a change is significant. They use mathematical equations to determine whether a change is significant.

When most people say that something is significant, they mean that the event or object has a great amount of importance. When scientists say that an observed change is significant, they mean that it is very likely the change was not caused by chance.

Reflection Section



- ✿ If you were one of the scientists doing this research, what would you recommend to managers wanting to increase the growth rate of *koa* crop trees?
- ✿ Is phosphorus important to the growth of *koa* trees? How do you know?

Discussion

The scientists believed that thinning alone did not improve growth because it would take more than 3 years for *koa* crop trees to respond to an increase in available sunlight. The scientists recommended that if thinning is the only treatment to be used, it should be done when the trees are young. The disadvantage of thinning at a young age has to do with the identification of crop trees and noncrop trees. When trees are younger, it is more difficult to identify which trees will become the best crop trees. When *koa* trees are older, the most

effective way to grow *koa* crop trees is to thin the noncrop trees, use herbicide to kill nonnative grasses, and apply phosphorus as a fertilizer.

Reflection Section

- ✿ How are *koa* wood guitars and phosphorus related?
- ✿ Why would thinning alone be best done when the trees are young?



Glossary

Biomass (bī ō mas): Living matter.

Dormant (dör mǝnt): Temporarily inactive.

Elevation (e lǝ vǎ shǝn): The height above the level of the sea.

Endangered (in dǎn jǝrd): Species whose continued existence is in danger.

Germinate (jǝr mǝ nǎt): Sprout or develop. Come into being.

Habitat (hǎ bǝ tat): The place or environment where a plant or animal naturally or normally lives and grows.

Herbicide ((h)ǝr bǝ sīd): A substance used to destroy or slow plant growth.

Native (nǎ tiv): Growing or living naturally in a particular place.

Nutrients (nū trē ǝnts): Substances that provide nourishment.

Organic (ǝr gǎ nīk): Of, relating to, or derived from living organisms.

Seedling (sēd līŋ): A young plant grown from seed.

Species (Spē sēs): A class of individuals having common characteristics and designated by a common name.

Sustainable supply (sǝ stǎ nǝ bǝl sǝ plī): Something that satisfies a need or wish and is managed so that it is not used up or permanently damaged.

Tropical (trǎ pi kǝl): Of or relating to a region or climate that is frost-free, with temperatures high enough to support year-round plant growth given sufficient moisture.

Accented syllables are in **bold**. Definitions and marks are from <http://www.merriam-webster.com>.

FACTivity



Note: This FACTivity can be used with any *Natural Inquirer* article.

Time Needed

40 minutes

Materials

- This article.
- Graphic organizer on page 37.

In this FACTivity, you will explore the reasons the scientists in this study might have chosen to be involved in the study. The question you will answer in this FACTivity is: Based on this FACTivity, what can you conclude about why each of these scientists became involved in this research project?

The method you will use to answer the question is: Reread the first paragraph in “Thinking About Science.” Then read one scientist’s statement at a time. Identify word clues or phrases from each statement that appear to be related to the research described in the article. Write word or phrase clues in the organizer below. In the last column, state the relationship between the clues and the research.

For example, in Mr. Scowcroft’s statement, the phrase, “forests have been turned into cattle pasture” is a phrase clue. This would be written in the second column. In the last column, you might state that, “Mr. Scowcroft studies *koa* forests that had earlier been turned into pasture.” This statement would be a sound conclusion because Mr. Scowcroft studied these areas during one of his favorite science experiences and the same type of area was studied in the article.

Scientist's last name and type of scientist	Clues from the scientist's statement	Relationship between clues and the research described in the article

Now answer the question posed at the beginning of this FACTivity.

Adapted from Scowcroft, P.G.; Friday, J.B.; Idol, T.; Dudley, N.; Haraguchi, J.; Meason, D. 2007. Growth response of *Acacia koa* trees to thinking, grass control, and phosphorus fertilization in a secondary forest in Hawai'i. *Forest Ecology and Management*. 239: 69–80. http://www.fs.fed.us/psw/publications/scowcroft/psw_2007_scowcroft001.pdf

Hoe a hoe ka Wa a a me He e nalu i ka waa kahiko

(Canoeing and Surfing in Ancient Hawai'i)

The first Polynesians in Hawai'i carved canoes and used these to travel over large distances. This is called *holomoana* or voyaging, a practice that continues today. In Hawai'i, *koa* trees are still shaped into canoes (**figure 14**). This is done for recreation and to keep alive the cultural practice and art of carving canoes. The art of carving canoes is called *kalai wa a*.



Figure 14. The best *koa* canoe trees are large, straight, and tall.

For Native Hawaiians and those who paddle traditional canoes, canoe building is a spiritual experience. In ancient times, canoe building was undertaken by traditional builders only after making customary offerings to the gods and receiving signs understood as blessings to

continue. Today, traditional offerings of thanks and respect are still practiced. From the time a decision was made to build a canoe until its first voyage, events were seen as good or bad omens. *Koa* trees were harvested in the mountain forests. The *elepaio*, a species of flycatcher, was observed over many days to note its tree-pecking behavior. If a *elepaio* was seen pecking into a tree, the tree was known to have insects. This would make it unsuitable for a canoe. Many of these traditional approaches to harvesting *koa* logs and shaping canoes are still practiced today.

Shaping a canoe from a solid *koa* log is complicated. After the canoe tree is cut, the future canoe is roughly shaped on the outside.

After the outside shaping is done, the inside is hollowed out. In the past, this was done with stone tools. Today, power tools are also used. After the inside is hollowed out, the canoe tree is light enough to be hauled from the forest to the shore. Hauling a canoe to shore was an important cultural event, requiring many people working (*laulima*) in unison (*lokahi*). The entire community celebrated this event. After bringing the canoe close to shore, the canoebuilder finished shaping the canoe. This work was so respected that no one was allowed to talk in the building while the canoebuilder was at work (**figure 15**).

Koa wood canoes are long and thin and require an outrigger for stability. An outrigger is made up of a long float (*ama*) attached to the canoe with two bars of wood (*iako*). An outrigger does more than prevent capsizing (**figure 16**). It keeps the canoe stable in even the roughest ocean conditions. Today in Hawai'i, *koa* canoes are special vessels. They



Figure 15. *Koa* wood canoes. Photo from the Bishop Museum, <http://www.bishopmuseum.org>.

Figure 16. The outrigger gives the long thin canoes incredible stability in even very rough water. Poster courtesy of Michael Van Dorn, Hawai'i artist, <http://www.vandornart.com>.



Why do you think canoe travel was important to early Hawaiians?

are used for racing and for ceremonies. *Koa* wood canoes are paddled by members of canoe clubs (*halau wa'a*) during races. These paddlers are continuing an ancient practice that is a foundation of traditional Hawaiian culture.

Another *koa* product is traditional surfboards (*alaia*). *Koa* was one of the three most common trees used for surfboards in ancient Hawai'i. *Koa* wood surfboards are still used today.

Surfboards came in many forms, shapes, and sizes. The long surfboards (*olo*) were carved from the *wiliwili* tree (*erythrina sandwicensis*). The *wiliwili* tree produces very light but strong wood. Surfboards from these trees were reserved specifically for nobility.

Ancient Hawaiians began using wooden boards to surf waves very early in Hawaiian history (figure 17). Although other early societies used surfboards, Hawaiian surfboard styles were more varied, and the Hawaiian art of surfing was more developed. Early Hawaiians created wood boards of various sizes so that different styles of surfing and different sizes of people could ride the waves.



Figure 17. *Koa* wood surfboards. Photo from the Bishop Museum, <http://www.bishopmuseum.org>.

Surfing remains a way of life in Hawai'i. Surfers ride waves today in the traditional manner. Paddling surfboards from a standing position has also become popular (figure 18). Surfing ocean waves is an art that was begun thousands of years ago in Hawai'i and will continue into the future.



Figure 18. Surfboards are sometimes paddled from a standing position. Photo by Dr. Ken Cordell.

Information from the Polynesian Voyaging Society, http://www.pvs.kcc.hawaii.edu/ike/kalai_waa/koakanu.html, and from the Surf History Preservation Collection, <http://www.woodsrfboards.com>.

Hawaiian saying:

E ola ke koa:
**Live like a *koa* tree;
Live a long time, like a *koa*
tree in the forest.**

(From <http://www.bishopmuseum.org>.)

Boa constrictors are snakes that live in Central and South America. They kill their prey by slowly squeezing it until it suffocates. Constrict means to stop or inhibit. The three things studied by the scientists in this study inhibited the fast growth of *koa* crop trees. That makes them *koa* constrictors!

Additional Web Resources

Gallery of *koa* tree photos by Dr. J.B. Friday:

<http://www.flickr.com/photos/jbfriday/sets/72157625383856739/show/>

Koa Ethnobotany information: Bishop Museum:

<http://data.bishopmuseum.org/ethnobotanydb/ethnobotany.php?b=d&ID=koa>

Anatomy of a Tree—Arbor Day Foundation:

<http://www.arborday.org/trees/RingsTreeNatomy.cfm>

History of the Polynesian Voyaging Society:

http://www.pvs-hawaii.com/about_pvshistory.htm

Using Polynesian noninstrument navigation:

<http://www.pvs-hawaii.com/navigation/summary.htm>

Building ancient *koa* wood surfboards:

<http://www.clubofthewaves.com/surf-culture/ancient-hawaiian-board-building.php>

National Education Standards

National Science Education Standard	Where and How the Standard Is Addressed
Abilities Necessary To Do Scientific Inquiry	Meet the Scientists: Description of their own scientific inquiry. Introduction: Identify questions. Introduction Reflection Section: Communicate procedures, critical thinking. Methods: Description of methods, What is DBH? Mathematics. Discussion Reflection Section: Explanation, critical thinking.
Understandings About Scientific Inquiry	Meet the Scientists: Different methods. Introduction: First and last paragraphs. Methods: Experimental design and mathematics. What is DBH?, figure 13, and Methods Reflection Section: Mathematics. Findings: Significant change.
Reproduction and Heredity	Method: Dormant seeds.
Regulation and Behavior	Phosphorus sidebar: Tree response to phosphorus.
Populations and Ecosystems	Introduction: Obstacles to growth.

Structure of Earth System	Meet the Scientists: Meason's soil description.
Populations, Resources, and Environments	Thinking About the Environment and Introduction: Wood products for society.
Understandings About Science and Technology	Discussion: Tradeoffs about when to use technology to thin.
Natural Hazards	Method: Effects of disturbance.
Science as a Human Endeavor	Thinking About Science: How scientists decide what to study. FACTivity: Reasons scientists like to study what they do.
Nature of Science	Findings: Significance sidebar.
National Curriculum Standards for Social Studies	Where and How the Standard Is Addressed
Culture	Thinking About the Environment: Dynamic culture. Canoeing and Surfing in Ancient Hawai'i: Human beings and culture.
People, Places, and Environments	Thinking About the Environment: Relationship between people and environment. Canoeing and Surfing in Ancient Hawai'i: Relationship between people and environment.
Global Connections	Figure 4 and Introduction: Demand for <i>koa</i> wood.
Production, Distribution, and Consumption	Thinking About the Environment: Demand for <i>koa</i> wood. Introduction Reflection Section: Production of wood, obstacles to meeting demand.



Mangrove Mania

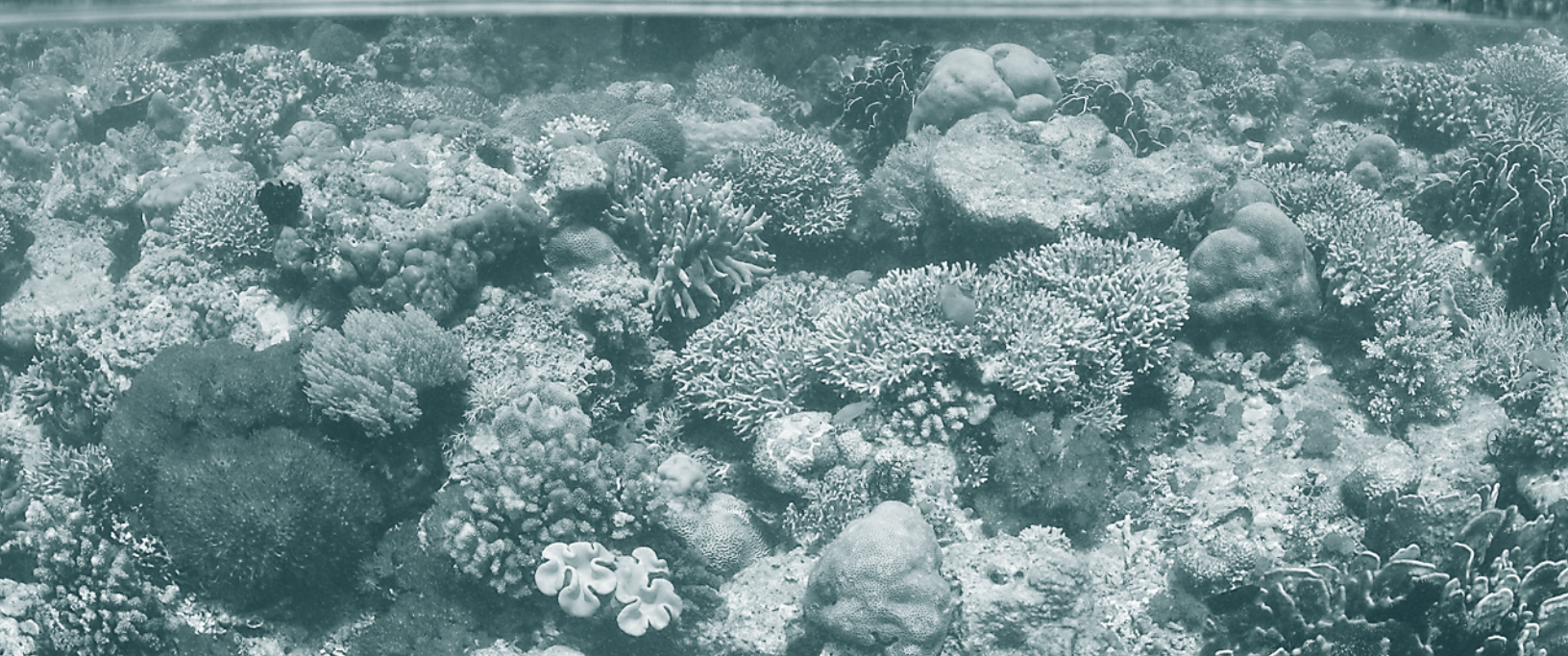


Photo courtesy of Brandon Cole Marine Photography.

***How Elevation Change
and Sea-Level Rise Affect
Mangrove Forests***

Meet the Scientists



◀ **Dr. Ken W. Krauss, Ecologist:** My favorite science experience is working directly with **land managers** to communicate the results of our scientific studies. Sharing this information helps the managers make important

land management decisions. I also enjoy the publication process, and I appreciate learning from other scientists with different viewpoints. **Peer review** and criticism promote excellence in science. In the picture, I am scouting for new tidal freshwater forested wetland study sites in the Savannah National Wildlife Refuge located in South Carolina.

▶ **Dr. Jim Allen, Forest Ecologist:** My favorite science experiences have been those that involve the opportunity to discover new things about forests. I enjoy working with the people who depend on the forests I've studied. I've also enjoyed all the travel opportunities that a career in science has provided. I have done fieldwork in beautiful places like Micronesia and the cypress swamps of the Southern United States. I have presented my research results at conferences in places like Alaska, Italy, and New Zealand.



Glossary words are in **bold** and are defined on page 49. Hawaiian words are in *italics* and their pronunciation is given on page 106.

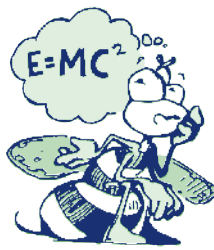
▶ **Dr. Katherine Ewel, Wetland Ecologist:** My favorite science experience was working with people in another culture to help them

see their natural environment from a different viewpoint. Making the right management decisions often depends on seeing a problem from many angles.

▼ **Ms. Nicole Cormier, Ecologist:** My favorite science experience has been traveling and working on tropical islands like those in the Federated States of Micronesia (FSM). I have been fortunate to work in old growth mangrove forests. I have also worked in one of the largest remaining freshwater *Terminalia* (a type of large tree) forests in the world on Kosrae, FSM. I learned a lot about how sea-level rise and climate change affect the mangrove ecosystem and its links to nearby fishing areas and to **coral reef** health. I have also learned how different cultures are linked to the forests and are dependent upon these mangroves for coastal protection, firewood, and fish.



Thinking About Science



Many different types of measurement are used in science. Measurement helps scientists compare things and make predictions. In this study the scientists measure several different **variables** over several years. Measuring something over time helps scientists figure out what might happen now and in the future.

To take **accurate** measurements, scientists use a lot of different types of **instruments**. You may use different instruments like beakers and scales in your science lab at school. Scientists

use these types of instruments as well as computers and calculators. Using the right instruments and making accurate measurements is important. In this study, you will learn about an instrument that scientists used to measure changes in the amount of soil on the surface of the land on two islands. This instrument helped scientists compare the amount of soil and **sediment** on the islands and enabled them to make predictions about future changes on these islands.

Be sure to read
“Unity in
Diversity”
on page 52.

Thinking About the Environment

Islands are constantly changing. The islands in this study are located in the **tropics (figure 1)**. The islands started as volcanic islands. Over time, rocks and other **debris** break down and sediment is formed. Environmental forces like wind and water move the sediment around.

The amount of sediment that is deposited changes the **elevation** of the land. On these islands, the change in elevation might be small. Even so, small changes could have large effects. Changes in elevation may lead to changes on the island. In the tropics, the changes in elevation and losses of sediment eventually cause the volcanic island to support a **barrier island** that then becomes an **atoll (figure 2)**. In this study, scientists were interested in how the elevation changes due to changes in sediment and a rise in sea level affect a certain type of forest called a mangrove forest.

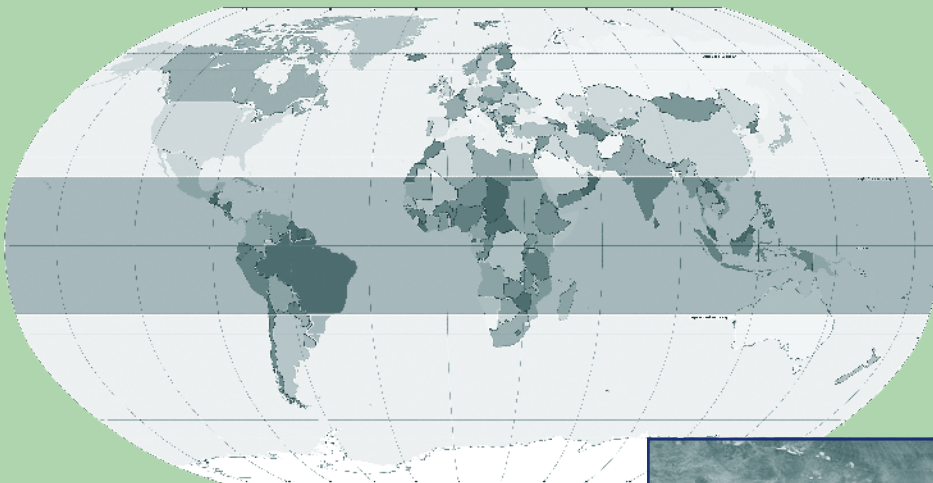
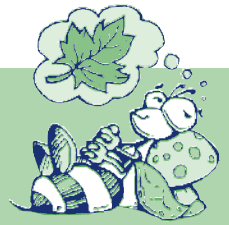


Figure 1. The tropics are near the equator. Image courtesy of <http://upload.wikimedia.org>.

Figure 2 (right). An atoll has a reef around a lagoon. This is the Pearl and Hermes Atoll, part of the Hawaiian Islands National Wildlife Refuge. Photo courtesy of the U.S. Fish and Wildlife Service.



Introduction

The scientists studied two islands, Kosrae and Pohnpei, in the Federated States of Micronesia (**figure 3**). Both of these islands have coastal mangrove forests (**figures 4a and 4b**). Mangrove forests are trees and shrubs found in the tropics that have large root structures and create barriers that help protect coastlines. These mangrove forests provide many benefits. The mangrove forests provide protection for the villages, agricultural areas, and other things on the island. This protective benefit is one way mangrove forests also help support the island's economy. These forests provide homes for fish and other wildlife. Because the mangrove forests are so important, the scientists in the study wanted to know how different elevation changes on the islands and sea-level rise affect mangrove forests.



Figure 4a (top) and figure 4b: Mangrove forests provide many benefits to people, animals, and land. Give one example of a benefit by looking at these pictures. Photos by Brandon Cole Marine Photography.

Figure 3. Kosrae and Pohnpei islands are located in the Central Pacific Ocean. Photo courtesy of USDA Forest Service/The Nature Conservancy.

What is sea-level rise?

Sea-level rise is the amount that sea level changes over time. Over the past 20 years, sea level has risen 3.302 millimeters a year. The rise in water levels has been linked to several things. One possible cause of sea-level rise is melting ice caps, glaciers, and ice sheets. Scientists are now studying other possible contributing factors. Scientists are interested in sea-level rise because as the sea level rises, some land that was once dry will be covered in water. Sea-level rise can also cause more erosion, flooding, loss of habitat, and **contamination of aquifers**. Sea-level rise can impact us in more ways. To learn more, visit <http://ocean.nationalgeographic.com/ocean/critical:issues:sea-level:rise/>.

Number Crunches

- How many inches did sea-level rise in the past 20 years? (Hint: Take amount of millimeters and multiply it by .039 to find out!)

Reflection Section

- Mangrove forests provide homes for fish and other wildlife. How could this help support the island's economy?
- What did the scientists want to learn in this study?



Methods

The scientists chose to study three different types of areas in which mangrove forests grow. The three areas were fringe, riverine, and interior. Fringe areas are on the exterior of the island and are subject to more wave action. Riverine areas are closer to rivers. The interior areas receive more protection from the waves, but are more affected by humans. On each island, the scientists chose two **river basins** to study. The scientists also included a **backswamp** area on Kosrae Island called Pukusruk (**figure 5**). Pukusruk was not directly affected by the river and is also protected from direct wave action (**figure 6**).

Kosrae Island	Pohnpei Island
1) Yela River	1) Enipoas River
2) Utwe River	2) Sapwalap River
3) Pukusruk (backswamp)	

Figure 5. Study locations on each island

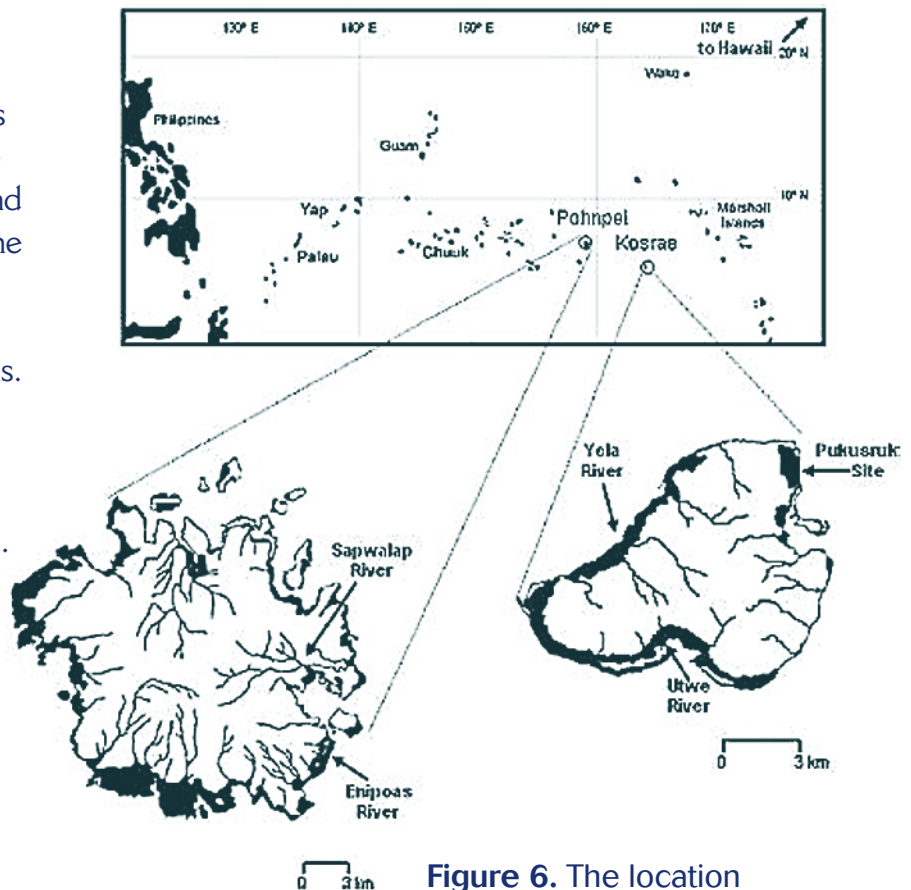


Figure 6. The location of each study site. The shaded areas are areas with mangrove forests.

At each of these sites, the scientists installed a surface-elevation table (SET) and aluminum pipes (**figure 7a and 7b**). The SET helps scientists figure out the **vertical** changes in soil surface. The SET enables the scientists to take repeated elevation measurements over time. The scientists arranged the SETs in four different directions in each measurement area. This arrangement enabled the scientists to take 36 measurements during each measurement period. A total of 39 SET pipes on the 2 islands measured conditions for 5 to 7 years. The scientists also measured the amount of **sedimentation**. The scientists placed 99 markers throughout the study areas (**figure 8**) and used a ruler to measure the sediment layer over time.



Figure 7a. The surface-elevation tables (SETs) helped to measure the vertical changes in the soil.



Figure 7b. Forest Service Ecologist Ken W. Krauss, now with the U.S. Geological Survey (USGS), takes surface elevation measurements in a mangrove forest on the island of Kosrae, Federated States of Micronesia. Photo courtesy of Dr. James A. Allen, Forest Service.



Figure 8. The scientists placed the markers throughout the study sites to measure sedimentation. Photo by Dr. Ken Krauss, USGS.

The scientists also gathered data on sea-level rise. The scientists had data on sea-level rise for Pohnpei but they did not have it for Kosrae Island. To be consistent and use the best possible data, the scientists used general sea-level trend data for the entire area in their calculations.

Reflection Section

- 🌿 Why do you think the scientists chose two different islands to study?
- 🌿 Why do you think scientists measured the islands for 5 to 7 years instead of just 1 or 2 years?



Findings

The riverine and interior zones along the Utwe River and the interior zone along the Yela River built elevation over the 6-1/2-year period (**figure 9**). Soil elevation at Pukusruk increased slightly until early 2002 when there was a **harvest** of nearby **overstory** trees. Then soil elevation decreased by 21 millimeters.

Location	Elevation Change
Yela Interior	0.91 millimeters/year
Utwe Riverine	3.29 millimeters/year
Utwe Interior	4.08 millimeters/year

Figure 9. Yearly elevation change over a 6-1/2-year period.

Overall, sedimentation rates were high over the time period that the scientists studied. Specifically, riverine and interior areas gained elevation over the time period studied. The fringe areas in all four river basins, however, lost elevation over the time period studied. The scientists also found that fringe and riverine zones were moderately **susceptible** to sea-level rise, with fringe zones being the most susceptible. The fringe zones are most susceptible to sea-level rise because they are closer to the sea and have the greatest amount of erosion. If the level of the water changes, it affects these areas more quickly.

Discussion

Understanding how sedimentation affects mangrove forests can help people who manage tropical forests make better decisions about how to use the land surrounding mangrove forests. In this study, harvesting had a negative effect on soil elevation. The less soil there is, the more susceptible an area is to rising sea levels. Scientists suggest that mangrove forests may need to be protected from nearby harvesting so that soil elevation is not negatively affected. The scientists in this study thought that this protection was particularly true for the fringe areas. These areas are more susceptible to sea-level rise and may not gain back the soil that would be lost during harvesting.

The scientists also found that continuous soil **deposition** is very important on these islands and helps with elevation levels relative to sea-level change. Continuous soil deposition means that through different processes such as weathering rock, soil is deposited in areas. This soil helps build the elevation of the area. Higher elevations protect the island from sea-level rise. Sea-level rise can greatly affect mangrove forests and other parts of the island ecosystem. Therefore, understanding soil deposition, elevation change, and sea-level rise helps scientists make the best recommendations for protecting the mangrove forests on these islands.

Reflection Section

- Why do you think harvesting of overstory trees may have affected the soil elevation?
- Why do you think fringe areas generally lost soil elevation over the time period studied?



Reflection Section

- Why is it important for tropical land managers to learn how best to manage the land around mangrove forests?
- Why is it important for people living on the islands to be concerned about rising sea levels?



Glossary

Accurate (ak yə rət): Free from error.

Aquifer (ak wə fər): A water-bearing layer of rock, sand, or gravel capable of absorbing water.

Atoll (a töl): A coral island consisting of a reef surrounding a lagoon.

Barrier island (bar ē ə r ī lənd): A long broad sandy island lying parallel to a shore that is built up by the action of waves, currents, and winds and that protects the shore from the effects of the ocean.

Backswamp (bak swamp): A wetland area that is not directly affected by wave energy.

Communal (kə myün əl): Shared by a group or community.

Contamination (kən tam ə nā shən): The act or process of making something harmful or unpleasant.

Debris (də brē): The accumulation of fragments of rock and wood.

Deposition (dep ə zish ən): The act or process of depositing. In this example, soil is deposited on the land from different processes like erosion and weathering.

Elevation (el ə vā shən): The height above sea-level.

Harvest (här vəst): The act or process of gathering in a crop or wood from a forest.

Instrument (in(t) strə mənt): A measuring device for determining the present value of a quantity under observation.

Land manager (land man ij ə r): A skilled individual who takes care of the land.

Matrilineal (ma trə li nē əl): Relating to family descent through mothers.

Navigation (nav ə gā shən): The science of getting ships, aircraft, or spacecraft from place to place.

Overstory (ō vər stōr ē): The layer of tree leaves and foliage in the tree canopy.

Peer review (pi(ə)r ri vyü): A process used for checking the work performed by one's equals (peers).

River basin (riv ə r bās ən): The land area drained by a river and its tributaries.

Sediment (sed ə mənt): Material deposited by wind, water, or glacier.

Sedimentation (sed ə mən tā shən): The act or process of depositing sediment.

Susceptible (sə sep tə bəl): Easily affected.

Tropics (träp iks): The region that surrounds the equator and goes from 23.5 degrees north latitude to 23.5 degrees south latitude.

Variable (ver ē ə bəl): Thing that can vary in number or amount.

Vertical (vərt i kəl): Going straight up or down from a surface.

Accented syllables are in **bold**. Definitions and marks are from <http://www.merriam-webster.com>.

Adapted from Krauss, K.W.; Cahoon, D.R.; Allen, J.A.; Ewel, K.C.; Lynch, J.C.; Cormier, N. 2010. Surface elevation change and susceptibility of different mangrove zones to sea-level rise on Pacific High Islands of Micronesia. *Ecosystems*. 13: 129–143.



Time Needed

1.5 to 2 hours

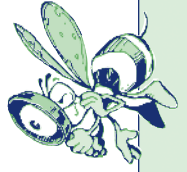
Materials

- Glass baking dish (7 x 11 inches).
- Piece of plywood, to fit partially inside the container at an angle (see picture), such as a 4.5-by-10-inch piece.
- Ruler.
- Ice cubes.
- Water.
- Small container of playdough or modeling clay.
- Permanent marker or dry erase marker.
- Blue food coloring.
- Masking tape (optional).

In this FACTivity, you will explore the idea of sea-level rise. This FACTivity has been adapted from the Digital Library for Earth Systems (DLESE) and the Deep Earth Academy at the Consortium for Ocean Leadership. For more information about similar activities and extensions, please visit <http://www.teachingboxes.org/sealevel/lessons/lesson2.jsp> and http://oceandrilling.coe.tamu.edu/curriculum/Sea_Level/Ice_Volume/teachers_notes.html.

All the world's ice can be divided into two types: sea ice (icebergs) and sheet ice (ice on land). Although both types of ice are at risk of melting if the average global temperature of the Earth increases, they have very different effects on the global sea level. In this activity, you will investigate what effect land ice will have on sea level.





Visit <http://www.teachingboxes.org/sealevel/lessons/lesson2.jsp> to find an activity that illustrates what happens when icebergs melt. Students can then compare and contrast these two activities and observe how each type of melting may or may not affect the amount that sea level will rise.

In addition, an excellent short video simulates these two activities can be found at http://oceandrilling.coe.tamu.edu/curriculum/sea_level/ice_volume/activity.html. The video reinforces concepts learned after the students complete the FACTivity.

Methods

1. Use the ruler to mark measurements every 2 millimeters from the bottom to the top of the glass dish so that you can measure any change in water elevation. You may do this on masking tape and then put the tape on the outside of the container or you may also try dry eraser markers on the outside of the dish.
2. Place the wood at an angle in the dish (see picture, opposite page).
3. Fill the dish with enough water to cover the bottom of the dish. Mark down this measurement under the "Start" box in the table provided.
4. Put about 3 drops of blue food coloring in the water.
5. Place playdough or modeling clay in a line just before the water. This line of playdough will keep the ice from sliding down as it melts. Make sure there are small open spaces in between each ball of playdough so the water can move through (see picture).
6. Place the bowl out into the sunlight.
7. Fill the board with ice cubes (see picture).
8. Re-check and record the water level and the amount of ice remaining every 20 minutes throughout the session.

Results and Discussion

Record your observations of the water level in the table below:

	Start	20 minutes	40 minutes	60 minutes	80 minutes	100 minutes	120 minutes
Water level							

1. How did the water level in the bowl change as the ice melted?
2. How can you explain your observation in question 1?

Unity in Diversity

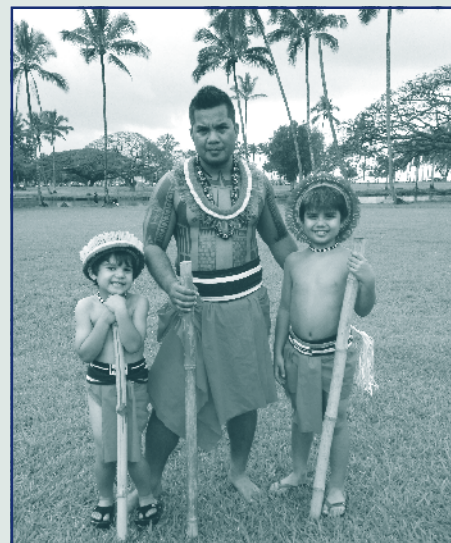
The Federated States of Micronesia (FSM) is made up of 607 islands. These islands are located in the Central Pacific Ocean (see figure 3 in the article). Four states make up the FSM: Pohnpei, Kosrae, Chuuk, and Yap. The total population of the FSM is approximately 100,000, and the official language is English. People living on these islands, however, speak eight major native languages: Yapese, Ulithian, Woleaian, Chuukese, Pohnpeian, Kosraean, Nukuoro, and Kapingamarangi. Because large expanses of water separate the islands, island groups have evolved some distinct cultural traditions. Several cultural traditions, however, are similar across the islands.

One cultural tradition that is similar across the islands is the maintenance of strong family bonds through the large extended family. Another common cultural tradition is the importance of clans or family groups. Today, however, the importance of clans has decreased for the island groups of Kosrae. People in Pohnpei, however, still emphasize **matrilineal** clans.

Micronesian people rely heavily on fishing and farming. Farming is focused primarily on tree crops like breadfruit, coconut, banana, and citrus. Root crops like yam, sweet potato, tapioca, and taro are also important. The coconut tree is a vital crop for survival on isolated islands. This tree is used to provide nourishment from the water, milk, and oil; the husk is used for fuel to cook food and make rope for building homes and canoes; and the leaves are woven for mats and roofing material. **Communal** labor and sharing are important and the tradition of giving gifts and respect to tribal leaders remains.

Even though the states have cultural practices that link people across Micronesia, each state and even island can have different customs and traditions. The people of Yap dress in customary clothing. Women wear grass skirts or fabric hand woven from banana fibers called a “lavalava” and men wear a type of loincloth called a “thu.” Fishing, farming, sailing, and weaving are a part of daily life. Dancing is an important cultural tradition. The dances tell their history and legends and are a form of entertainment. Children are encouraged at an early age to learn these special dances.

The people of Yap are also famous for their stone money. This money was carved from stone in distant islands and brought to Yap through treacherous journeys by traditional canoes. The stones are so large that a hole had to be carved in the middle of the stone. This hole enabled a wooden post to be inserted in the middle that would be held by multiple people to carry it. Today, the traditional stone money lines the pathways in front of the village cultural houses. Here, they are held just as money would be held in a bank. Each stone holds a history that impacts its value, and the owner is known by everyone in the village.



Mr. Jermy Uowolo displays traditional Yapese tattoos. He and his sons Mykah (left) and Jayden (right) are wearing thus. The striped belts are made from hand-woven fabric called lavalava.” *Photo courtesy of Amanda Uowolo.*

The stone money is still used today for important exchanges of high cultural value.

In the state of Chuuk, woodcarvers make beautiful masks and items for use in the home and sea craft, among other objects. The most accomplished wood

carvers also build canoes and boats high in the hills of inner islands and then bring these boats down to the sea when they are nearly complete. It is common to see women on these islands waist deep in mangrove forests looking for delicacies among the sea life. The women use open-hearth fires to cook daily meals.

In Pohnpei, communities will come together to build a new boathouse or just to complete daily chores. The people here are known for their energetic cultural dances. They use these dances to pass on tradition, language, and family unity.

In Kosrae, native people practice singing and chanting as cultural traditions. Weaving, woodcarving, canoebuilding, and housebuilding are important to the people of Kosrae.

A special relationship exists between Hawaiians interested in traditional ways and the FSM. Before **navigation** instruments were available, Polynesians made ocean voyages across wide expanses of open ocean. Some of these Polynesians settled on the islands of Micronesia and some on the islands of Hawai'i. Polynesian sailors used the horizon, stars, weather, wind and wave patterns, the feel of ocean swells, clouds, ocean and sky colors, and wildlife movements to keep track of their location, direction, and speed. These sailing techniques were passed along in word and song and were often kept secret.



Traditional canoe house on the Yapese island of Fais, which has no electricity and no cars. *Photo courtesy of Amanda Uowolo.*

By 1975, there were no Hawaiians who knew these ancient navigation techniques. At that time, Master Navigator Mau Pailug of the FSM was only one of six navigators who still used these techniques. Of the six, only Mau was willing to share his knowledge with the Hawaiians.

He was asked by the Polynesian Voyaging Society to teach them how to navigate in the ancient manner. Mau's willingness to share this knowledge helped to increase pride in traditional Hawaiian and Polynesian culture. This pride has led to a growing interest in voyaging, canoe building, and noninstrument navigation that unites the Pacific Islands.

For more information, visit <http://visit:fsm.org> or <http://traveltips.usatoday.com/micronesi:culture:11238.html>.

For a lesson plan on noninstrument navigation, visit: http://www.sciencebuddies.org/science-fair-projects/project_ideas/Astro_p008.shtml. A computer and Internet connection is required for this lesson.

Additional Web Resources

National Geographic's Mangrove Page:
<http://ngm.nationalgeographic.com/2007/02/mangroves/warne:text>

Smithsonian Institution Ocean Portal Site on Mangroves:
<http://ocean.si.edu/ocean:life:ecosystems/mangroves>

History of the Polynesian Voyaging Society:
http://www.pvs-hawaii.com/about_pvshistory.htm

Using Polynesian non-instrument navigation:
<http://www.pvs-hawaii.com/navigation/summary.htm>

National Education Standards

National Science Education Standard	Where and How the Standard Is Addressed
Abilities Necessary To Do Scientific Inquiry	Thinking About Science: Measurements and instruments used to measure. Introduction Reflection Section: State the research question. Methods: Technology, observation, measurement. Findings: Evidence. Findings Reflection Section: Drawing conclusions from data.
Understandings About Scientific Inquiry	Thinking About Science: The importance of measurement and using instruments to make accurate measurements. Introduction Reflection Section: Hypotheses and research questions. Number Crunches: Math is important in scientific inquiry. Methods: Implementing an experiment, instruments used to take measurements. Methods Reflection Section: Understanding the importance of using more than one test site, understanding the importance of recording observations, understanding the importance of gathering data over different lengths of time. Discussion Reflection Section: Implications and further study.
Structure and Function in Living Systems	Introduction: Structure and function of mangrove forests.
Regulation and Behavior	Introduction, Findings, and Discussion: Importance of mangrove forests and effects of sea-level rise and sedimentation on mangrove forests.
Populations and Ecosystems	Introduction: Importance of mangrove forests in the ecosystem. Method, Findings, and Discussion: How soil sedimentation helps stabilize mangrove forest areas.
Diversity and Adaptation of Organisms	Introduction: Importance of mangrove forests.
Structure of Earth System	Thinking About the Environment: Sediment formation. Methods: Sedimentation, changes in soil elevation, sea-level rise.
Populations, Resources, and Environments	What is sea-level rise? Sea-level rise. Findings: Harvesting.
Science and Technology in Society	Methods: Technology used to study sediment elevation change and sea-level rise. Findings and Discussion: Answers to scientists' research question and implications of those findings.

Understandings About Science and Technology	Methods: Using technology to measure sediment change over time and sea-level rise.
Science as a Human Endeavor	Meet the Scientists: Personal stories. Thinking About Science, Introduction, and Introduction Reflection Section: What the scientists were interested in studying.
Nature Of Science	Thinking About Science: Measurement and scientific instruments. Introduction: The applied nature of science (solving a problem). Discussion: Implications and the application of science to solve problems.

National Curriculum Standards for Social Studies	Where and How the Standard Is Addressed
Culture	The Federated States of Micronesia cultural essay. Introduction and Introduction Reflection Section.
Time, Continuity, and Change	The Federated States of Micronesia cultural essay.
People, Places, and Environments	Thinking About the Environment. Introduction. Method. Findings. Discussion. The Federated States of Micronesia cultural essay. Figures 1, 2, 3, 4.
Individual Development and Identity	The Federated States of Micronesia cultural essay.
Production, Distribution, and Consumption	Introduction. Discussion.
Science, Technology, and Society	Meet the Scientists. Thinking About Science. Thinking About the Environment. Introduction. What Is Sea-level Rise sidebar. Methods. Findings. Discussion. FACTivity. The Federated States of Micronesia cultural essay.
Global Connections	The Federated States of Micronesia cultural essay.

Beam Me Down, Scotty

***The Use of
Airborne
and Satellite
Technology
To Measure
Carbon in
Hawaiian
Forests***

Photo courtesy of NASA.

Meet the Scientists

► **Dr. Greg Asner**, Tropical Ecologist: My favorite science experience occurred in 2009 when my team and I climbed upward from the Amazon forests into the Andes mountains in Peru. After we made it to the mountain **summit**, we could look back, eastward, and see thousands of lightning strikes in the storms that normally occur over the Amazon forest. It made me think of standing on the summit of *Mauna Loa* in Hawai'i, looking down on the incredible Hawaiian rainforests that still exist high above where people live along the coast. Photo courtesy of Greg Asner, Carnegie Institution for Science.



▼ **Dr. R. Flint Hughes**, Ecologist: My favorite science experience was working with local villagers in the rain forests of southern Mexico. I was working to understand how **deforestation** and **land use** were changing those forests and all the incredible insects, birds, and other animals living within them. During this time, I had the opportunity to see and learn about the beautiful, large trees and associated plants of those forests. I saw and heard howler monkeys, toucans, and multicolored snakes that made those forests their home. I also saw first-hand how the people living in and around such



ecosystems—the people who became my friends—profoundly affect the ecosystems in order to exist themselves.

Working with the villagers affected me deeply. It was a real-world example of the common

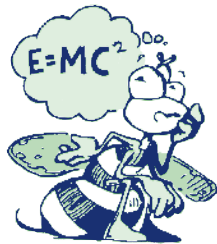
conflict between the livelihoods of people and the preservation of valuable tropical forests that are in danger of being lost forever. That experience fueled my motivation and desire to understand and protect native forests in Hawai'i and elsewhere in the world.

▼ **Ms. Amanda Uowolo**, Forest Ecologist: My favorite science experience occurred while collecting data on **species diversity**, **density**, and size in a forest in the Republic of Palau. We had our noses to the ground looking at tree seedlings. We came across a newborn fruit bat that had fallen from his mother's wing in the tree canopy. We rescued the baby bat and named him Henry. These types of surprises are what make my job exciting. This is often how scientific research works: You go into a situation expecting to find something specific, but end up finding the unexpected.



Glossary words are in **bold** and are defined on page 65. Hawaiian words are in *italics* and their pronunciation is given on page 106.

Thinking About Science



You know that scientists do research to learn new things. They also do research to test what they believe to be true. Scientists may also do research to improve scientific methods. New types of technology are available all of the time. You can see changes in technology in the way that cell phones continue to be improved. Research that explores the use of new technologies helps all scientists to use the new technologies. Scientists use these technologies to tackle important questions in new ways that help us better understand our planet.

In this research, the scientists combined three different ways of gathering information:

an older, traditional method along with two new technologies. The older method involved going out into the forest to collect information by hand. The two new technologies involved airplanes, satellites, and computers. By combining these three methods of collecting information, the scientists were able to produce new information. This new information increases our understanding about 1 million hectares of land—an area about the size of Connecticut. This research enabled the scientists to test a new scientific method that will help other scientists do research about large, **diverse** areas of forest.

Be sure to read
“Mālama ‘āina”
on page 68.

Thinking About the Environment

Every tree contains carbon. If you remove the liquids from a tree, about one-half its weight is carbon. When trees are growing, they help to combat climate change by absorbing carbon from the atmosphere. Trees store carbon in their wood. When trees are cut and burned, the carbon in them is released back into the atmosphere in the form of carbon dioxide (CO₂). There, it contributes to climate change by heating our planet. It is, therefore, important to protect our forests worldwide. When forests are left standing and protected, their carbon is kept out of the atmosphere and the forests are able to collect and store even more carbon.

Scientists want to know how much carbon our forests contain. Knowing the amount of carbon is the only way to keep track of any change over time. In a way, tracking the amount of carbon is like keeping track of your own weight. If you never weighed yourself, it would be hard to say for sure whether or how much

weight you were gaining or losing. When you think about the amount of carbon in forests, you can see what a big job this tracking is. Forests cover a lot of land and are different in terms of their structure and types of species that live there. Scientists need to use new tools and technologies, therefore, to help them estimate how much carbon large areas of forests contain.



Carbon dioxide in the atmosphere

Without a certain level of carbon dioxide in the atmosphere, Earth would be too cold, and life as we know it could not exist. Within the past 100 years, however, more and more carbon dioxide has been **emitted** into the atmosphere. Too much carbon dioxide causes the planet to warm beyond its normal range. This increase in carbon dioxide emissions comes from human activities, such as burning fossil fuels. Although too much carbon dioxide in the atmosphere is contributing to global climate change, it is important to remember that a certain level of carbon dioxide in the atmosphere is necessary for life on Earth.

Introduction

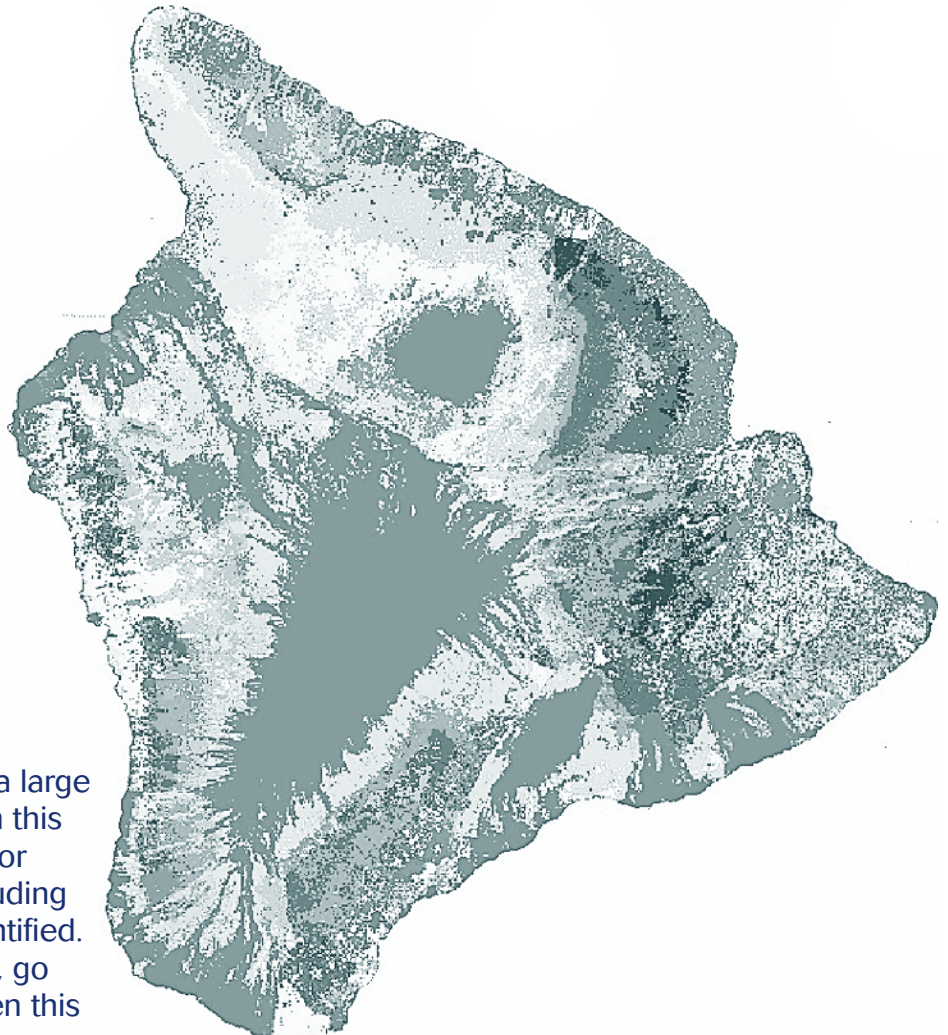
You may have heard about carbon trading and carbon credits. These phrases refer to programs aimed at reducing carbon dioxide emissions to the atmosphere. These programs involve balancing an amount of carbon emissions with activities that reduce an equal amount of emissions. If someone were driving across the United States, for example, his or her car would **emit** a certain amount of carbon dioxide during the trip. To make up for these emissions, the driver might voluntarily contribute money to an organization that protects forests. To balance the car's emissions, the driver would have to know three things: (1) how much carbon dioxide the car would emit during the trip, (2) how much forest land would contain that same amount of carbon, and (3) how much money it would take to help protect that much forest land.

In this study, the scientists were interested in the second item. They wanted to test a method of calculating the amount of carbon stored by plants across a large area of land. They chose the island of Hawai'i to test their method. Hawai'i is the largest island in the Hawaiian Islands (**figure 1**). It contains 1,000,000 hectares. Hawai'i has volcanoes, forests, pastures, grasslands, developed areas, and many types of **ecosystems** and land cover (**figure 2**). Hawai'i is one of the most **ecologically** diverse places on Earth. It has areas with high rainfall and also deserts with low rainfall. It has areas at sea level and at very high **elevations**. Each of these areas contain a different amount of carbon. Forests, for example, hold more carbon than grasslands.



Figure 1. Hawai'i is the largest of the Hawaiian Islands.

Figure 2 (at right). Hawai'i contains a large variety of ecosystems. Each shade on this map represents a unique ecosystem or **land cover**. Forty types of areas, including ecosystems and land covers, are identified. To see or download this map in color, go to <http://www.naturalinquirer.org>, open this journal and click on this article.



Number Crunches

- How many acres is 1,000,000 hectares? Multiply the number of hectares by 2.47 to find out.
- How many square kilometers is 1,000,000 hectares? Divide by 100 to find out.

In the past, people working directly on the land estimated the amount of carbon stored in plants. This method, although fairly accurate for the actual trees being measured, was expensive and took a long time to get enough **samples**. In addition, this method could estimate only the amount of carbon in small areas of land. This information was not enough to understand forests across large areas. Remember that there is now a need to understand how much carbon large areas of forest and other types of land cover store. To meet this need, the scientists decided to combine the old method with new technologies.

The scientists used new laser technology called Light Detection and Ranging (LiDAR). The scientists also used satellite technology that estimates how much land has certain types of vegetation. Combining old and new methods enabled the scientists to estimate the amount of carbon stored in different types of forests. They could then create a carbon map of the whole island of Hawai'i.

Reflection Section



- Why did the scientists study Hawai'i?
- What was the problem the scientists were trying to solve?

What is LiDAR?

LiDAR stands for Light Detection and Ranging. Light beams, or laser pulses, are sent from an airplane towards Earth. When the light beams reach something on Earth, they are reflected back to the airplane. A computer onboard calculates how long it takes the light beam to return. Because we know the speed of light and the technology can measure time accurately, the computer can calculate the distance between the airplane and the object on Earth that was hit by the light beam. Using LiDAR, scientists can calculate the height of many trees across large areas. When LiDAR is used in forests, some of the light beams travel through the leaves before being reflected back. This characteristic of LiDAR enables scientists to estimate the amount of vegetation between the ground and the treetops (**figure 3**).

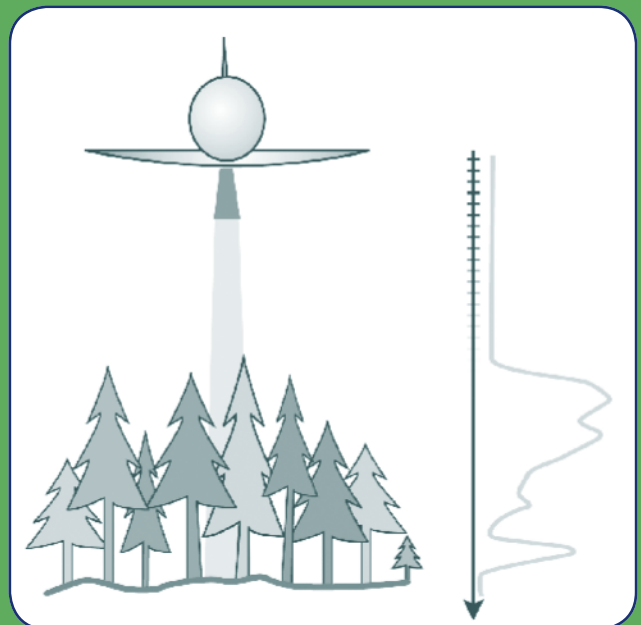


Figure 3. LiDAR enables scientists to measure vegetation over large areas of land.

Methods

The scientists used four steps to test their method for carbon mapping. First, they used existing maps of the land cover of Hawai'i. People working on the land created some of these existing maps, and satellites and computers created others (**figures 4 and 5**). Using these maps, the scientists identified the land cover of different areas. Using information from the satellite and a computer program, they identified areas that had forests and areas with no forests or those that might have been **deforested** (**figure 6**). Have you used Google Earth to see objects on Earth close up? If you have, you can see how the scientists identified conditions of forests and other areas on Hawai'i using satellite photos. Google Earth uses Landsat photos, just like the scientists did.

The scientists then used LiDAR to better understand the **vertical** structure of the plants and trees (**figure 7**). About 25 percent of the island was sampled. The areas sampled included a wide variety of land cover and ecosystems.

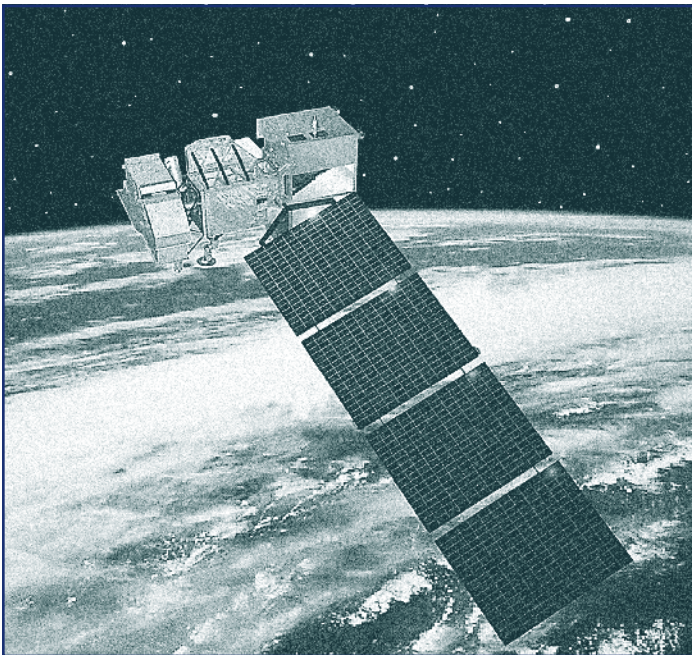


Figure 4. The National Aeronautics and Space Administration, or NASA, uses satellites to take photographs of Earth from space. This satellite is called Landsat. Scientists use Landsat to study Earth's land cover. Image courtesy of NASA.

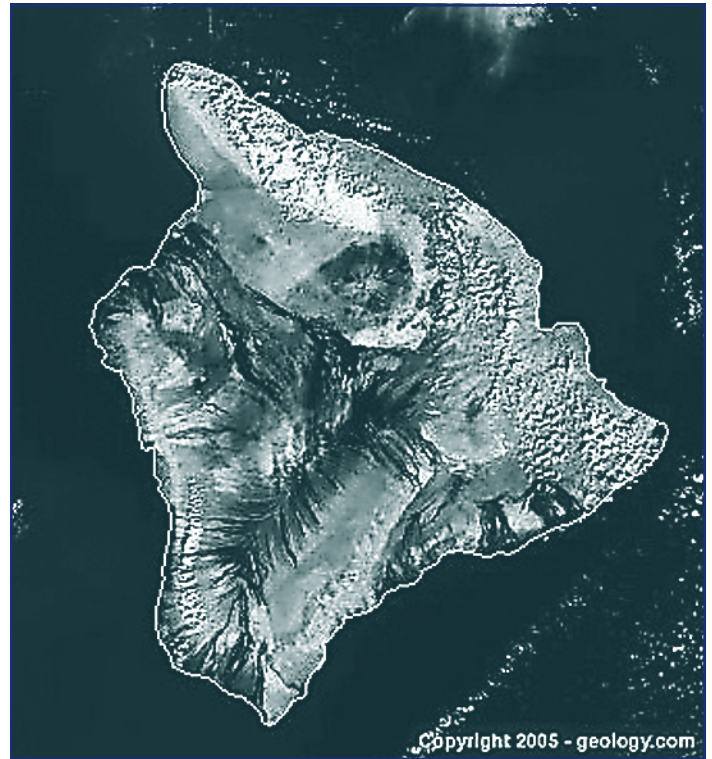


Figure 5. A Landsat photograph of Hawai'i. Image courtesy of <http://geology.com>.

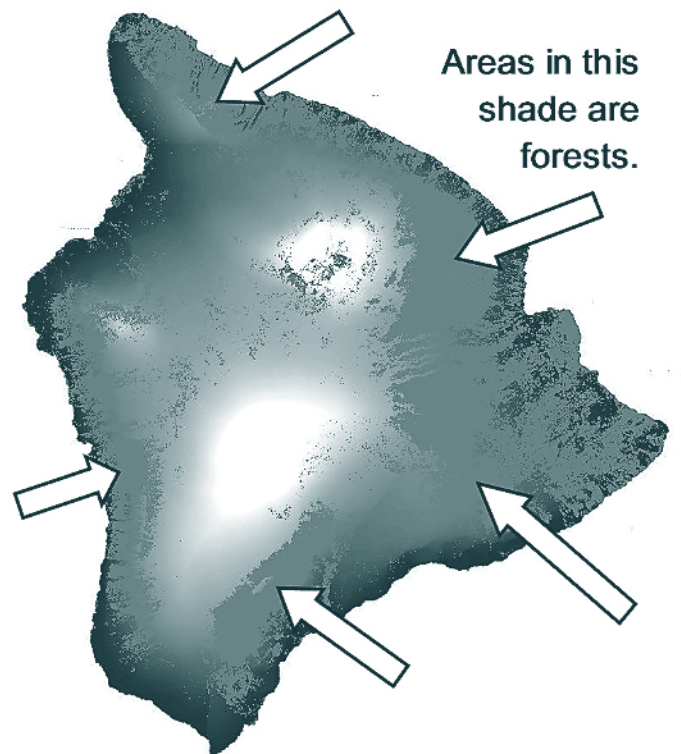


Figure 6. This map shows forests and other areas on Hawai'i. A computer program called CLASlite, which stands for Carnegie Landsat Analysis System-Lite, created this map.



Figure 7. The vertical structure of a forest is the way the vegetation looks from the ground up to the treetops. Compare the vertical structure of these four different forests. What is similar and what is different about the vertical structure of these forests?

The third step was to identify areas on land to study in person. The scientists identified 126 areas for sampling where they established plots. Each plot was an imaginary circle with a radius of 30 meters. Each of these 126 plots had also been sampled using LiDAR. In each plot, the scientists identified and measured all trees that were 5 centimeters or larger diameter at breast height (DBH) (see sidebar). The scientists then used existing equations that related DBH to the amount of carbon in the tree. For example, trees with a DBH of 5 to 7 centimeters were already known to contain a certain amount of carbon. In this way, the scientists were able to estimate the amount of carbon contained in each of the 126 plots.

Number Crunches

- ❖ What was the diameter of each of the 126 plots?
- ❖ What was the area of each plot? Area is calculated using this formula: $A = \pi(r^2)$, where A =area, π =3.14, and r =radius. This formula is also written $A = \pi r^2$.

What is DBH?

DBH stands for diameter at breast height. In the United States, this distance is 1.4 meters (about 4.6 feet) from the ground. This method is a standard way to measure the size of trees (**figure 8**). When the tree is growing on a hill, DBH is measured on the uphill side of the tree.



Figure 8. One way to measure the size of a tree is to measure its diameter at breast height. Photo by Paul Scowcroft.

In Step 4, the scientists looked at the LiDAR information on vertical structure in each of the 126 plots. They compared this information with their direct measurements of the plants' carbon content. The scientists discovered that the amount of carbon in each plot was related to the center of the vertical height of the trees. If the scientists could calculate the center of the vertical height of any forested area in Hawai'i, they could estimate the amount of carbon being held in that area. Plots with taller trees, for example, held more carbon. In other words, the scientists found that by using LiDAR to identify the average height of the trees in an area, they could accurately estimate the amount of carbon stored by plants in that area.

The scientists then combined the vegetation maps that they used in Step 1 with the carbon estimates made using LiDAR in Step 4. If they identified an area as being deforested or **degraded** (Step 1), they reduced their estimate of the amount of carbon in that area. This method enabled them to apply the carbon estimates to each of the land cover areas in the existing maps. By applying carbon estimates to each area of land, they were able to create a carbon map of Hawai'i.

Reflection Section



- How was the old method of estimating carbon in person combined with new technologies?
- What if the scientists wanted to map the carbon contained in the State of West Virginia? Should they use the same estimate of carbon related to the vertical center as they did in Hawai'i? Why or why not?

Findings

The scientists discovered that the amount of carbon in an area was related to the type of soil and climate conditions in the area. Areas with older Hawaiian soils contained more carbon than areas with young soils. Areas of Hawai'i with high rainfall contained more carbon than areas with lower rainfall. The scientists also found dry areas, whether they were warm or cool, contained smaller amounts of carbon (**figure 9**).

The scientists discovered that areas with little or no forest land contained less carbon than forested areas. Forests that had been planted in the 1930s in areas where rainfall was plentiful contained the highest amount of carbon.

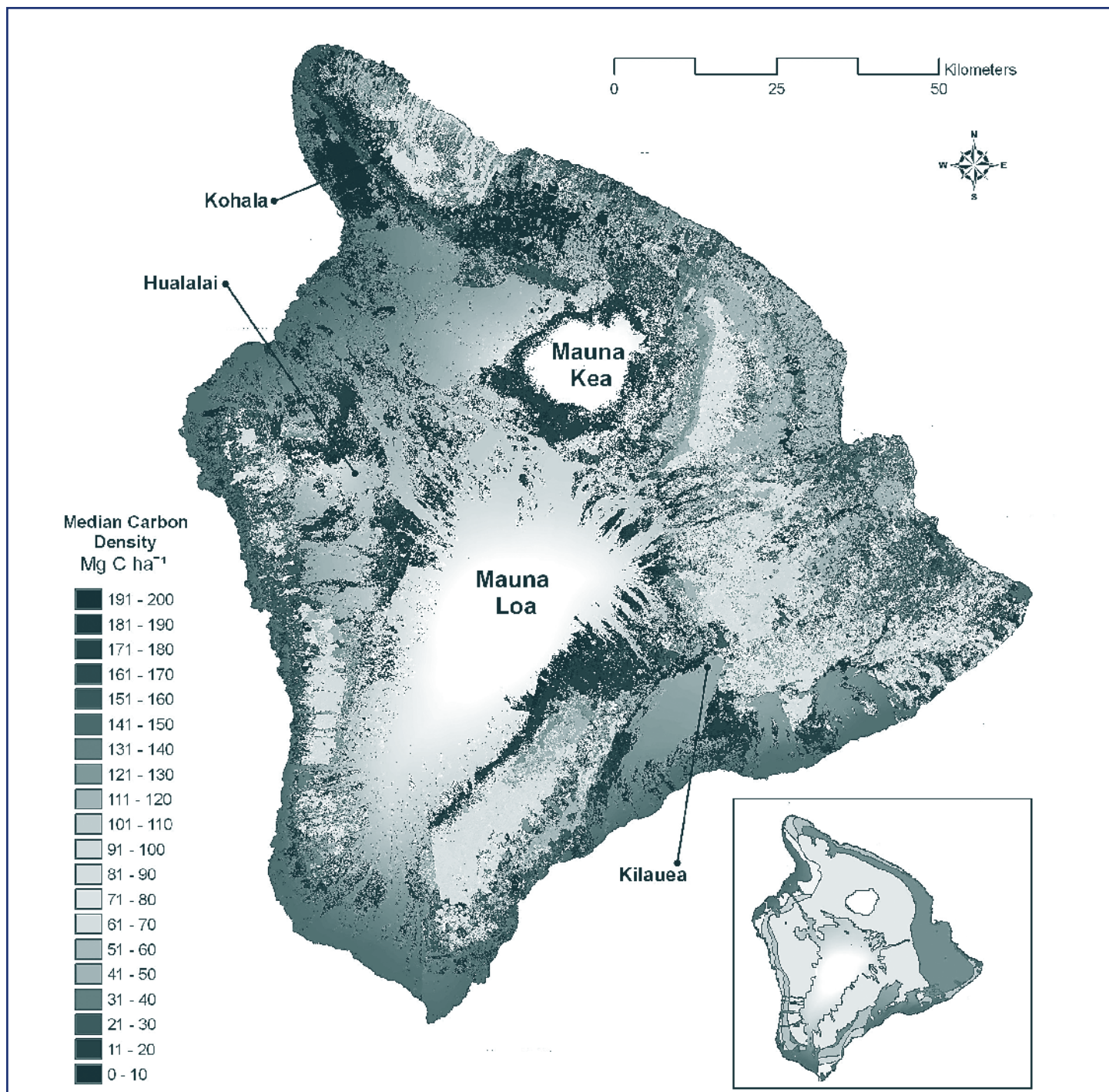


Figure 9. Carbon map of Hawai'i. In these two colors, the areas with the highest and lowest levels of carbon appear the same. In full color, however, these differences would be visible. To see the map in color, look at the cover of this journal. You may also visit <http://www.naturalinquirer.org> and click on this journal and this article to view the map in color. The inset shows the level of detail in carbon mapping available prior to this method being tested. What differences do you see? Compare this map with the Landsat image in figure 5.

Reflection Section

- ❖ Why would areas with old soils contain more carbon than areas with young soils?
- ❖ Why do you think the amount of carbon was related to the amount of rainfall in different areas of Hawai'i?



Discussion

The scientists concluded that the use of LiDAR to estimate carbon is as accurate as making the estimates in person. Because LiDAR can be used over a large area, the cost of using LiDAR is much less than trying to make in-person estimates over the same large area. Using LiDAR, moreover, enables scientists to make carbon estimates in remote areas people would have a hard time visiting.

The scientists also concluded that after they made an initial carbon map, they can easily update it using Landsat photographs that show changes in land cover over time. In particular, Landsat photographs will show the locations of new deforestation and degradation as well as new forest growth. Existing carbon maps can be updated to show the decrease or increase in carbon storage due to these conditions.

Reflection Section



Would you say that the scientists' test of their new method to estimate the amount of carbon in Hawai'i was successful? Why or why not?

Do you think that this method could be used for other large areas of forest and other land cover? Why?

Adapted from: Asner, G.P.; Hughes, R.F.; Mascaro, J.; Uowolo, A.; Knapp, D.E.; Jacobson, J.; Kennedy-Bowdoin, T.; Lark, J.K. 2011. High-resolution carbon mapping on the million-hectare Island of Hawai'i. *Frontiers in Ecology and the Environment*: 110301094720075 DOI: 10.1890/100179. [http://www.fs.fed.us/psw/publications/hughes/psw_2011_hughes\(asner\)001.pdf](http://www.fs.fed.us/psw/publications/hughes/psw_2011_hughes(asner)001.pdf).

Glossary

Deforest (dē fōr əst): The act or process of clearing forests.

Degrade (di grād): To lower the character of.

Density (den(t) sə tē): The quantity of something per a particular space, length, or volume. A measure of how close things are to one another.

Diverse (di vərɪs): Differing from one another.

Diversity (də vər sə tē): The condition of having or being composed of differing elements; variety.

Ecological (ē kə lāj i kəl): Having to do with ecology. Ecology is the study of the relationship of living things with each other and their environment.

Ecosystem (ē kō sis təm): A system made up of an ecological community of living things interacting with their environment especially under natural conditions.

Elevation (el ə vā shən): The height above the level of the sea.

Emit (ē mit): To throw or give off or out.

Land cover (land kəv əv): The observed cover of Earth's surface, such as vegetation and manmade features.

Land use (land ūs): The way the land is being used, such as for homes, agriculture, roads, or forests.

Sample (sam pəl): A part (as a set of individuals chosen from a whole population) used for investigating the whole.

Species (spē sēs): A class of individuals having common characteristics and designated by a common name.

Transpiration (tran(t)s pə rā shən): The process by which plants give off water vapor through the stomata in their leaves.

Vertical (vərt i kəl): Going straight up or down from a level surface.

Accented syllables are in **bold**. Definitions and marks are from <http://www.merriam-webster.com>.



Time Needed

1 class period

Materials

- This article.
- The article, “The GLAS Is Half Full,” from the Climate Change edition of the *Natural Inquirer*. You may download this article at <http://www.naturalinquirer.org/satellites-and-changing-tropical-forests-a-109.html> or order the Climate Change edition from <http://www.naturalinquirer.org>.
- Graphic organizers on pages 66-67.

In this FACTivity, you will answer the question, “What are the similarities and differences of two recent studies of carbon storage in

tropical forests?” It is your job to identify how these studies are alike and how they are different.

The method you will use to answer this question is: Read “Beam Me Down, Scotty.” Then read “The GLAS Is Half Full” from “Thinking About the Environment” through the “Discussion” section. You do not need to do the Reflection Sections.

Now, compare and contrast “Beam Me Down, Scotty” with “The GLAS Is Half Full” by completing the first graphic organizer on page 67. After you have completed the graphic organizer, hold a class discussion about your findings. Then, summarize your findings by completing the second graphic organizer below.

Graphic Organizer: Summarize

What are three differences between these two studies?	
What are three similarities between these two studies?	
Write a research question that all of the scientists in these two studies could answer together.	

Graphic organizer: Compare and contrast the two studies.

	Beam Me Down, Scotty	The GLAS Is Half Full
What question did the scientists want to answer?		
How was carbon involved in the research?		
Name four characteristics of the land being studied.		
What was the role of in-person information collection?		
How were Landsat photographs used?		
How was LiDAR used? (GLAS is a type of LiDAR)		
What did the scientists conclude about the use of technology to collect information?		

Mālama 'Āina (Care for the Land)

This research highlights the importance of Hawaiian forests as places where carbon is stored on Earth. When forests are healthy, more carbon is stored on Earth. This can prevent more carbon dioxide, or CO₂, from entering the atmosphere. Most CO₂ enters the atmosphere from burning fossil fuels. Too much of this gas contributes to the planet's warming. Reducing CO₂ in the atmosphere, therefore, will slow climate change.

Forests also provide other benefits. They provide homes for animals, protect soil and water, and provide places for people to enjoy. Forests provide wood and nontimber products for buildings, furniture, musical instruments, medicine, food, and art. We recognize these benefits of forests today. Because we recognize these benefits, we take action to protect our forests. Did early Hawaiians understand the benefits they received from their forests? If so, did they take action to protect their forests? What did they do?

In 1987, Marion Kelley concluded that early Hawaiians had a strong tradition of caring (*mālama*) for the land (*'āina*). They had an unwritten rule to take only what was needed from the island forests. This unwritten rule was explained by the following proverb: "*Hahai no ka ua i ka ulula'au*,"—"The rains always follow the forests." Early Hawaiians observed that rains were associated with forests. We know now that tropical forests

are dense and trees are tall where rain is plentiful. We also know that tree growth results in **transpiration** that can create mist and clouds that encourage rain. Because water is critical to life, the early Hawaiian observations about the relationship between rain and trees served them well. They cut down only the trees they needed. By cutting only what they needed, they made sure that rains would continue coming to their forests. Because they took only what they needed, the forests were available for generations of Hawaiians to use and enjoy.

The forests of Hawai'i are still loved and cared for today. In the Hawaiian Islands, the concept of *mālama 'āina* is passed from parents to children. For example, Kamuela Meheula-Naihe of the First Nations' Futures Program, wrote "As a *keiki*, I spent most of my time outdoors. My parents taught me the concept of *mālama 'āina* at a young age. I grew up always having a garden, spending a lot of time at the ocean and in the mountains. Because of these experiences...I am deeply connected to the environments around me." (From <http://www.fnfp.org/>.)

How do the people in your family and community feel about the land? How do you feel about using forests and protecting them? What can we learn from the concept of *mālama 'āina*?

The title of this article is based on the TV show, Star Trek. "Beam me up, Scotty" is the command Captain Kirk reportedly gave to his chief engineer, Montgomery "Scotty" Scott, when he needed to be transported back to the Starship Enterprise. Although this phrase is close to what was said on the show, these actual words were never used on the show. In this research article, light beams were sent down to Earth from an airplane using LiDAR and reflected back to the airplane. In a way, these light beams were being beamed down from and back up to a "starship."

Additional Web Resources

NASA Landsat Resources for Educators:

<http://landsat.gsfc.nasa.gov/education/resources.html>

National Oceanic and Atmospheric Administration
Carbon Cycle Education Resources:

http://www.education.noaa.gov/climate/carbon_cycle.html

First Nations' Futures Program:

<http://fnfp.org/>

World's Forest edition of the *Natural Inquirer*:

<http://www.naturalinquirer.org/>

National Education Standards

National Science Education Standard	Where and How the Standard Is Addressed
Abilities Necessary To Do Scientific Inquiry	Introduction: Use of math in science. Introduction Reflection Section: Communicate scientific procedures, identify questions. Method Number Crunches and What Is DBH?: Mathematics. Methods Reflection Section: Develop explanations, use appropriate tools and techniques. Findings Reflection Section and Discussion Reflection Section: Develop explanations. FACTivity: Identify questions, communicate procedures.
Understandings About Scientific Inquiry	Thinking About Science: Investigations generate new methods, use of technology. Thinking About the Environment: Technology improves data collection and analysis. Figures 3 and 4: Using technology in the investigation. Methods: Type of method used, method fits the problem, math is important, technology is used. Discussion: Conclusions about using technology. FACTivity: Analysis of methods used.
Structure and Function In Living Systems	Figure 6: The vertical structure of a forest.
Populations and Ecosystems	Introduction and figure 2: Diversity of ecosystems in Hawai'i.
Structure of Earth System	Thinking About the Environment: Carbon in trees. Carbon Dioxide in the Atmosphere: Function of carbon dioxide. Findings: Relation of carbon to soil. Findings Reflection Section: Soil structure and volcanic eruptions.
Understandings About Science and Technology	What is LiDAR?: Technology provides access to otherwise unobservable phenomena. Discussion: Technology has tradeoffs.
Natural Hazards	Thinking About the Environment and carbon dioxide in the atmosphere: Hazards of rising carbon dioxide.

Science and Technology in Society	Thinking About Science: Technology can cause change in society.
Science as a Human Endeavor	Meet the Scientists: Science requires different abilities.
Nature of Science	Methods: The use of existing information (land cover maps, DBH-carbon equations).

National Curriculum Standards for Social Studies	Where and How the Standard Is Addressed
Time, Continuity, and Change	<i>Malama 'āina</i> : Comparison of historic attitudes towards forest use, comparison of forest values over time.
People, Places, and Environments	<i>Malama 'āina</i> : Reasons for early Hawaiian views.
Individual Development and Identity	<i>Malama 'āina</i> : Reflection on current values.
Production, Distribution, and Consumption	Introduction: Balancing carbon emissions (production, distribution, and consumption).
Science, Technology, and Society	Entire article: How might this technology affect society?
Global Connections	Entire article: Global climate change concerns.



***Don't Litter
the Stream!***

Photo courtesy of Richard MacKenzie.

***An Invasive Tree Species and
a Hawaiian Stream Food Web***

Meet the Scientists



◀ **Dr. Trisha Atwood**, Food Web Ecologist of Marine and **Aquatic Ecosystems**: My favorite science experience was when I was collecting a tissue/**DNA** sample from a dead whale floating off the coast of Hawai'i so that we could try and identify what **species** it was.

I had to collect the sample with a pocket knife by hanging off the side of a tiny boat while about 10 of Hawai'i's most dangerous sharks swam underneath me eating the whale. This experience was super scary, but also very fun!

▶ **Dr. Tracy Wiegner**, Aquatic Biogeochemist (**hī ō gē ō kām ist**): My favorite science experience was hiking along the *Waipi'o Valley* rim in the cloud forest to collect samples from the streams dropping into the valley. I lay in the streambed on my stomach and looked over the waterfall cliff into the valley below (hundreds of feet). It was breathtaking. The stream was also beautiful. It was a blackwater stream and the water looked like concentrated iced tea. The streambank was lined with brilliant green moss and the **riparian** forest was comprised of **pygmy ohia** trees. This stream is one of the prettiest I have ever seen. Photo by Mike Gomes.



Glossary words are in **bold** and are defined on page 80. Hawaiian words are in *italics* and their pronunciation is given on page 106.

▶ **Dr. Jason Turner**, Marine Ecologist: I think every day is my greatest science day because, in this field, you never know what is around the corner. Last week, I helped recover the lower jaw of a 55-foot sperm whale; this week, I am scuba diving doing fish and coral surveys; next month, I will be studying sharks. As a scientist, every day is a new adventure!



▼ **Dr. Richard MacKenzie**, Aquatic Ecologist: When I was little, I used to come home from the creek behind our house covered in mud. I still do. I love that I get to study fish, insects, and shrimp in really amazing streams, wetlands, and mangrove forests. It is always exciting to put on my mask and snorkel and stick my face in the water to see some brightly colored fish or shrimp looking back at me (unless it's an eel). One particular moment I remember was when we were sampling fish from a mangrove out on Yap Island in the Federated States of Micronesia. The moon was not visible that night, and it was pitch black as we kayaked out to the mangrove forest. Every time I put my paddle in the water, it would light up with **bioluminescence** from all the little microbes in the water.



What kind of scientists did this research?

Be sure to read
“Water Is Wealth”
on page 85.

Aquatic Biogeochemist: This kind of scientist studies the movement of chemical elements, such as carbon and nitrogen, through marine and freshwater aquatic ecosystems. These scientists also study how chemical elements relate to and become a part of living things over time.

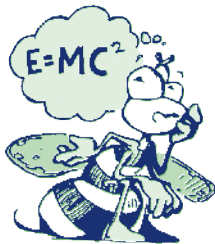
Aquatic Ecologist: This kind of scientist studies the relationship of species living in marine, stream, or lake environments with their living and nonliving environments.

Food Web Ecologist of Marine and Aquatic Ecosystems: This kind of scientist studies the structure of marine (saltwater/ocean) and freshwater aquatic (including streams, lakes, wetlands) food webs and includes the plant and animal species that make up those food webs.

Marine Ecologist: This kind of scientist studies the relationship of species living in marine environments with their living and nonliving environments.

Thinking About Science

Most of the time, it seems that environmental scientists study the natural world that we can see. Some of them, however, also study parts of the natural world that are too small for us to see. Atoms, for example, are too small to be seen by the naked eye. As the building blocks of all matter, however, they are important for scientists to understand.



The scientists in this study used special technology to study nitrogen atoms. All living and once-living things contain nitrogen atoms. Nitrogen atoms can be different from one another. Living things, for example, contain two types of nitrogen atoms. The difference is slight but gives scientists the ability to learn interesting things.

Scientists can identify the proportion of different kinds of nitrogen atoms in living and once-living things. The scientists in this study used this ability to better understand a stream's food web.

Thinking About the Environment



A food web is the pattern of **consumption** in an **ecosystem**. A food web describes what eats what in an ecosystem. Food webs begin with primary producers. These are mostly green plants and some bacteria. Primary producers convert the Sun's energy into **organic** energy. Some kinds of animals eat only plants or bacteria. Many animals (and a few plants) consume animals. Some animals eat both plants and animals. All these animals (and some plants) are called consumers. When a consumer eats a plant or an animal, the atoms that made up the plant or animal are transferred to the consumer.

Over many years, plant and animal species adapt to their environment. Their role in the food web helps to **sustain** a healthy ecosystem. This means that the types of atoms a consumer receives from eating a plant or an animal help to maintain the food web as it has adapted over the years.

In this study, the scientists were interested in learning about the food web in a Hawaiian stream. They wanted to know if the amount of nitrogen in the stream's food web was changing because of an invasive tree species growing along the stream's edge.

Introduction

From 1920 to 1950, a tree species called albizia (*Falcataria moluccana*) was brought to Hawai'i from islands located north and northeast of Australia (**figures 1 and 2**). Albizia trees were planted to grow new forests and for landscaping. A fast-growing tree, albizia now grows all over Hawai'i. Albizia has been so successful, it is taking over the places where **native** trees have grown.

The scientists in this study had observed an increase in nitrogen in some Hawaiian streams. The places where nitrogen was increasing were areas with albizia trees growing along the streams. When albizia leaves fall to the ground, they eventually decay. The nitrogen in the leaves goes into the soil. Over time, this nitrogen can get into streams. Some of the albizia leaves fall directly into the stream. The scientists wondered if **aquatic** organisms were eating these albizia leaves. If the organisms were eating the albizia leaves, then albizia trees may be changing the nature of Hawaiian stream food webs. This is because, naturally, Hawai'i has little nitrogen in its plants, soil, and streams.

Nitrogen is the most abundant gas in the atmosphere. Some atmospheric nitrogen gets into soil and organic matter on the ground. Although all plants need nitrogen, most plants cannot use it in its atmospheric or free form. Bacteria found in soil, organic matter, and in the roots of certain plants like the albizia tree can change free nitrogen into forms of nitrogen that other plants can use. This change is called nitrogen fixation. Because albizia trees are able to fix nitrogen themselves, they grow quickly.

When albizia leaves fall to the ground, they contribute nitrogen to the nitrogen-poor Hawaiian soil. Hawaiian soils are low in nitrogen because they were formed from recent volcanic eruptions. Over tens or hundreds of thousands of years, nitrogen fixation by bacteria and plants causes Hawaiian soils to become slowly richer in nitrogen. Because Hawai'i is still a young island, however, it does not have much nitrogen in its soils.



Figure 1. Albizia growing on the island of Hawai'i.

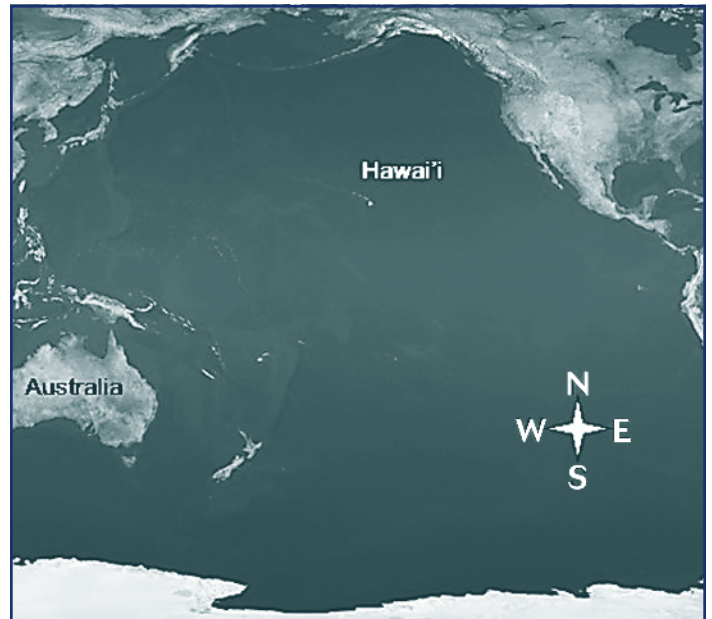


Figure 2. Albizia was brought to Hawai'i from islands located north and northeast of Australia. What is the most likely form of transportation used to move albizia to Hawai'i? Why do you think that is so?

Usually, aquatic organisms in Hawaiian streams eat algae (**figure 3**). Algae are aquatic primary producers (See “Thinking About the Environment”). The scientists thought that albizia **leaf litter** might be replacing algae as the base of the food web. They wanted to know whether organisms living in Hawaiian streams with albizia trees growing nearby were eating albizia leaf litter instead of native algae.



Figure 3. Algae in St. Marks National Wildlife Refuge, Florida. The stream studied by the scientists had algae in it as well. Photo courtesy of Steve Hillebrand and U.S. Fish and Wildlife Service.

Reflection Section



-  State what the scientists wanted to know in the form of a question.
-  Review “Thinking About Science.” How do you think the scientists might have answered their question?

Methods

The scientists had to find streams to study that were alike in almost every way. To answer their question, the presence of albizia trees growing nearby should have been the only difference between the streams. The scientists located two different areas of one stream. This stream had

an upstream area that had no albizia trees and a downstream area that was invaded by albizia trees (**figures 4 and 5**). The scientists measured three times the amount of nitrogen in the stream’s water where the albizia trees were growing. Otherwise, the stream areas were similar.



Figure 4. This upstream area was not invaded by albizia trees.



Figure 5. This downstream area was invaded by albizia trees.

The scientists collected samples of the following from each area:

- Particulate organic matter, or POM (small bits of organic matter in the water)
- Algae
- Caddisfly larvae (moth-like organisms whose larvae are aquatic) (**figure 6**)
- A species of amphipod (small, shrimplike organisms) (**figure 7**)
- American swamp crayfish (**figure 8**)
- Swordtails (**figure 9**)
- Guppies (**figure 10**)



Figure 8. Crayfish, not native to Hawai'i, also live in the water. You might have found crayfish in streams near your home or school. Photo courtesy of the U.S. Fish and Wildlife Service.



Figure 6. Caddisfly larvae live in the water. Caddisflies are not native to Hawai'i.



Figure 9. Swordtails, a popular aquarium fish, are found in Hawaiian streams but are not native to Hawai'i.



Figure 7. Amphipods, native to Hawai'i, look like shrimp.



Figure 10. Guppies are a popular aquarium fish found in Hawaiian streams. Guppies are not native to Hawai'i.

In the downstream area, the scientists also collected albizia leaves from the shore. All of the samples were collected within a few weeks of each other in August 2006.

Using technology called an isotope ratio mass spectrometer (spek trā mə tər), the scientists identified which kind of nitrogen atoms and what

proportion of each was present in everything but the albizia leaves (**figure 11**). They did this identification by testing small pieces of the consumers' tissues. Then the scientists used a special computer program to identify the source of food in the consumers' diets.

Reflection Section

- ❦ Why did the scientists have to find streams that were alike in every way except for the albizia trees growing nearby?
- ❦ Finding higher-than-normal levels of nitrogen in the tissues of consumers might lead the scientists to what conclusion about albizia leaves as a food source?
- ❦ Reading the captions of figures 6–10, what might you conclude about the aquatic organisms in this stream?



Figure 11. A ratio mass spectrometer.

Findings

Recall from “Thinking About Science” that living things contain two kinds of nitrogen. The scientists found that the plants and animal species living in the stream area with no albizia contained a smaller proportion of one type of nitrogen than the species living in the area with albizia (**figure 12**).

In a food web, some animals eat plants and some eat plants and other animals. These animals may themselves become food for other animals.

Tables 1 and 2 show the estimated percentage of each food source for each consumer. Note that in table 2, albizia is included as a food source.



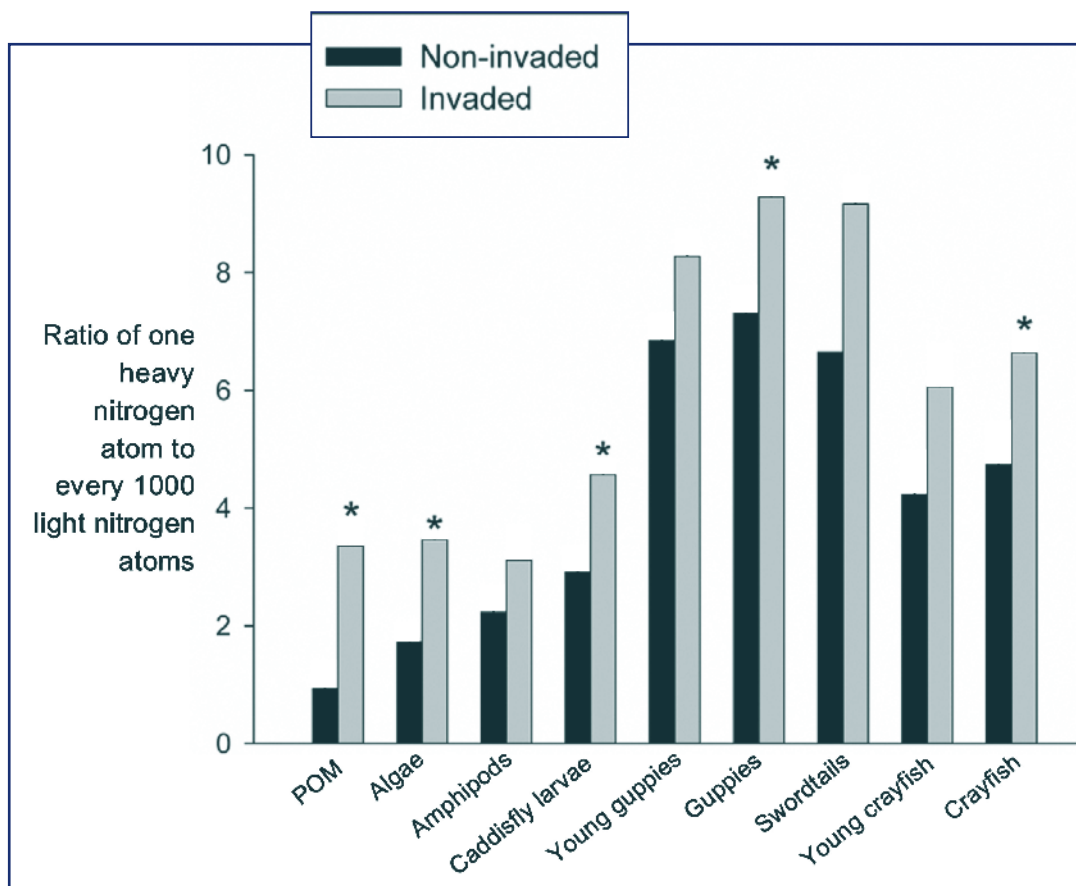


Figure 12. The scientists found a greater proportion of one type of nitrogen in the plant and animal species living in the stream area with albizia. Although the pattern was similar for every plant and animal species studied, not all the differences can be considered certain. When scientists are fairly certain that an observed or measured difference is not caused by chance, they say it is a significant difference. In this figure, significant differences are shown by the addition of an asterisk (*) above the bar.

		Consumer						
		Amphi-pods (% of diet)	Caddisfly larvae (% of diet)	Swordtails (% of diet)	Guppies (% of diet)	Young guppies (% of diet)	Young crayfish (% of diet)	Crayfish (% of diet)
Diet	POM (Particulate Organic Matter)	<10	≈50	0-5	0-5	0-15	0-48	0-14
	Algae	>90	≈60	0-10	0-8	0-31	0-83	0-24
	Amphi-pods			15-39	0-14	12-83	8-100	73-100
	Caddisfly larvae			61-85	86-100	17-88	0-49	0-15
	Swordtails						0-13	0-4
	Guppies						0-11	0-3
	Young guppies						0-13	0-4

Table 1. The estimated percentage of food source for consumers in the stream area with no albizia trees. (Note: < means "less than," > means "greater than," and ≈ means "approximately")

		Consumer						
		Amphi-pods (% of diet)	Caddisfly larvae (% of diet)	Swordtails (% of diet)	Guppies (% of diet)	Young guppies (% of diet)	Young crayfish (% of diet)	Crayfish (% of diet)
Diet	Albizia leaves	73-81	31-73	0-3	0-4	0-4	4-7	0-13
	POM (Particulate Organic Matter)	0-20	0-49	0-33	0-24	0-24	85-96	43-83
	Algae	0-27	0-69	0-36	0-26	0-26	0-10	0-53
	Amphipods			0-20	0-20	0-19	0-4	0-17
	Caddisfly larvae			64-87	75-100	74-100	0-2	0-15
	Swordtails						0-2	0-16
	Guppies						0-2	0-13
	Young guppies						0-2	0-16

Table 2. The estimated percentage of food source for consumers in the stream area with albizia trees.

Reflection Section



- Look at the way the numbers occupy the cells in tables 1 and 2. Both show a pattern from left to right. Why do the cells increase from left to right?
- Compare the first row in tables 1 and 2. What does this row reveal about albizia as a food source?

Discussion

The fallen leaves of trees growing along streams can be a source of food for aquatic consumers. When the leaves are from an invasive species, the food web may change. In the case of this Hawaiian stream food web, the invasive albizia tree changed the diet of amphipods and caddisfly larvae living in the stream. The leaves, which became their preferred food, provided more nitrogen to these animals than is found under natural conditions.

Because amphipods and caddisfly larvae are a food source for other animals, the higher levels of nitrogen will be passed up the food web.

If albizia continues to spread across Hawai'i and especially along streams, the natural stream food web could change from one of native origin to one of invasive origin. If albizia trees invade across Hawai'i, many other changes could occur that would change the stream food webs across Hawai'i.

Reflection Section



- 🍃 If the stream food webs change across Hawai‘i because of albizia, do you think the food webs that exist on the land beside streams could change as well? Why or why not?
- 🍃 An increase in nitrogen in Hawaiian streams may cause more algae to grow. If more algae grow, how might the stream be further changed by albizia?

Adapted from Atwood, T.B.; Wiegner, T.N.; Turner, J.P.; MacKenzie, R.A. 2010. Potential effects of an invasive nitrogen-fixing tree on a Hawaiian stream food web. *Pacific Science*. 64(3): 367–379. [http://www.fs.fed.us/psw/publications/mackenzie/psw_2010_mackenzie\(atwood\)001.pdf](http://www.fs.fed.us/psw/publications/mackenzie/psw_2010_mackenzie(atwood)001.pdf).

Glossary

Aquatic (ə kwät ik): Growing or living in or often found in water.

Bioluminescence (bī ō lū mā ne sən(t)s): The light coming from living organisms; the light so produced.

Consumption (kən səm(p) shən): The act of eating or drinking.

DNA (D N A): Acronym that stands for Deoxyribonucleic (dē äk si rī bō n(y)u klē ik) acid. DNA is found in cells and determines traits. Different animal species have unique DNA sequences, making it possible to identify the species from a small sample of tissue.

Ecosystem (ē kō sis təm): A system made up of an ecological community of living things interacting with their environment, especially under natural conditions.

Endemic (en dem ik): Found especially and often only in a certain locality or region.

Invasive (in vā siv): Tending to spread. In this case, a nonnative species that takes over the habitat of native species.

Larva (lär vā): A young, wingless, often wormlike form (as a grub or caterpillar) that hatches from the egg of many insects.

Leaf litter (lēf lit ə): Fallen and decaying leaves.

Medicinal (mə dis nəl): Tending or used to cure disease or relieve pain.

Native (nā tiv): Living or growing naturally in a particular region.

Organic (ör gan ik): Of, relating to, or obtained from living things.

Pygmy (pig mē): A person or thing very small for its kind.

Riparian (rə per ē ən): Relating to or living or located on the bank of a natural watercourse (as a river).

Sample (sam pəl): A part (as a set of individuals chosen from a whole population) used for investigating the whole.

Species (Spē sēs): A class of individuals having common characteristics and designated by a common name.

Sustain (sə stān): To give support to.

Sustenance (səs tə nən(t)s): Supplying or being supplied with the necessities of life.

Summit (sə mət): The highest point.

Accented syllables are in **bold**. Definitions and marks are from <http://www.merriam-webster.com>.



Time Needed

One class period (50 minutes).

Materials

- The food web circles on pages 83-84. (copied on card stock if possible).
- Sheet of plain paper for calculations.
- Pencil.
- String or yarn.
- Tape or glue.
- Scissors.

In this FACTivity, you will answer the question:
What are some ways that albizia leaves may

be changing the Hawaiian stream food web?
The method you will use to answer this question is:

Using the information in tables 1 and 2 (in the article you have just read), complete the tables below. To do this, use plain paper to calculate the average percentage in each cell of tables 1 and 2. Because a range is given, you will use only two numbers to calculate the average. Then, round the average percentage to the nearest whole percentage and write it in the cell below. If a range is not given, round the percentage or use the percentage given. The first row is completed as an example. Leave the white columns blank for now.

Upstream area without albizia (Calculate from table 1, page 78)

	Amphipods (average whole %)		Caddisfly larvae (average whole %)		Swordtails (average whole %)		Guppies (average whole %)		Young guppies (average whole %)		Young crayfish (average whole %)		Crayfish (average whole %)	
POM (Particulate Organic Matter)	Less than 10	1	50	5	3	0	3	0	8	1	24	3	7	1
Algae														
Amphipods														
Caddisfly larvae														
Swordtails														
Guppies														
Young guppies														

Downstream area with albizia (Calculate from table 2, page 79)													
	Amphipods (average whole %)		Caddisfly larvae (average whole %)		Swordtails (average whole %)		Guppies (average whole %)		Young guppies (average whole %)		Young crayfish (average whole %)		Crayfish (average whole %)
Albizia leaves													
POM													
Algae													
Amphipods													
Caddisfly larvae													
Swordtails													
Guppies													
Young guppies													

Using the formula below, write a number in the white columns for each cell of each table:

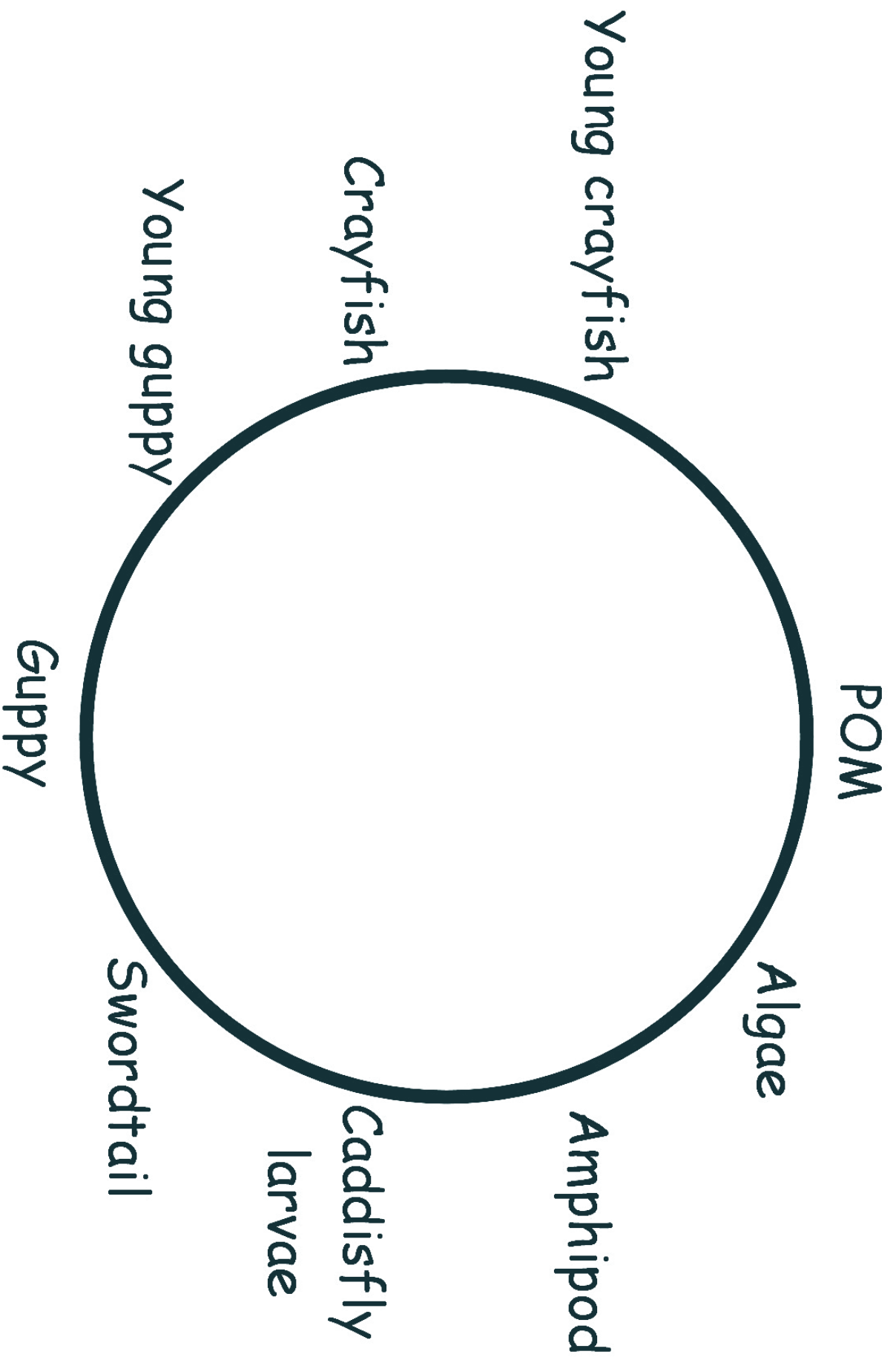
If the percentage is:	You write:
Between 0 and 5	0
Between 6 and 10	1
Between 11 and 20	2
Between 21 and 30	3
Between 31 and 40	4
Between 41 and 50	5
Between 51 and 60	6
Between 61 and 70	7
Between 71 and 80	8
Between 81 and 90	9
Between 91 and 100	10

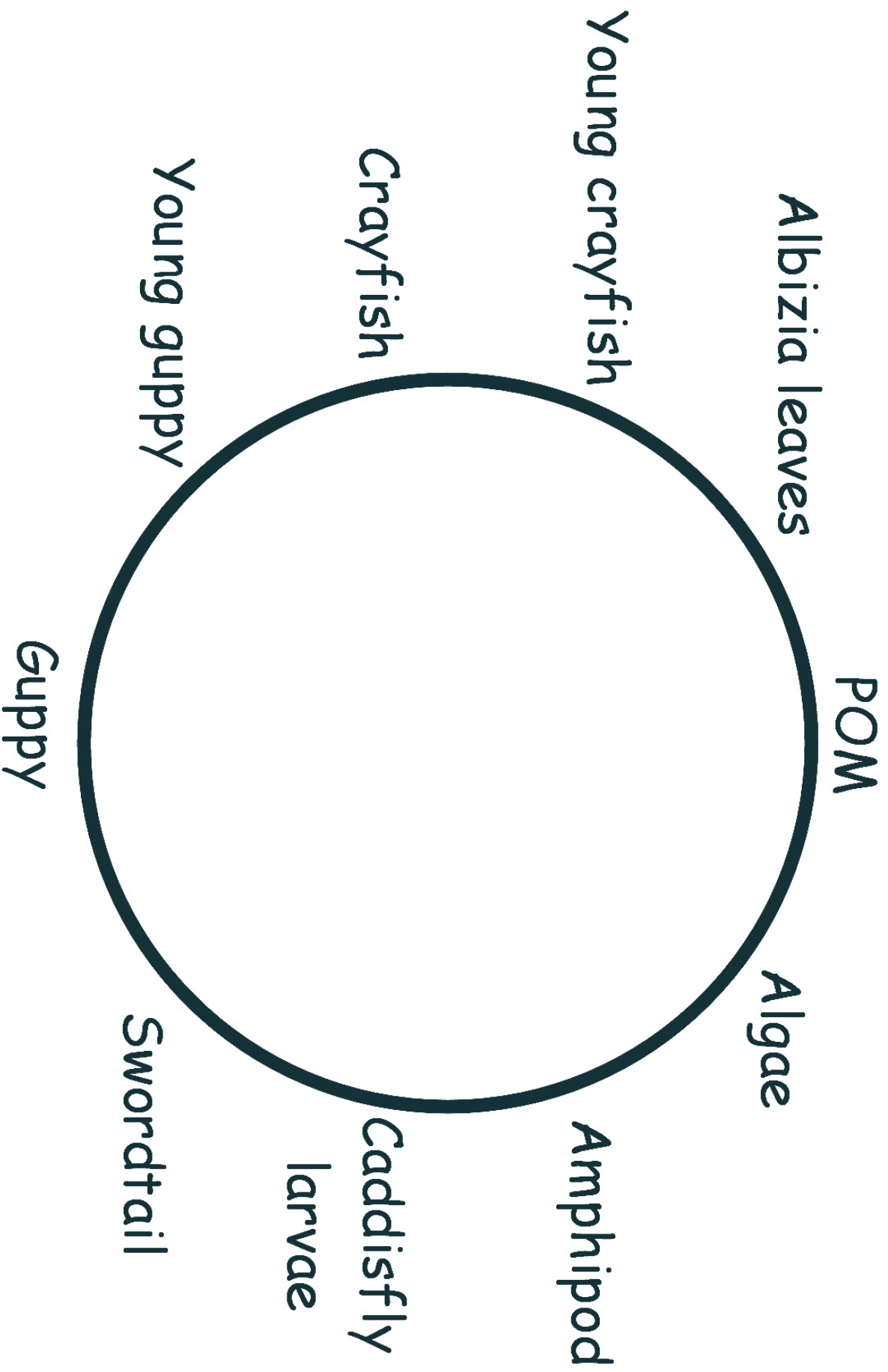
Using the numbers from 1 to 10, you will complete the food web tables on pages 81-82. For example, in the first table, less than 10 percent of the amphipods' diet is POM. About 50 percent of the caddisfly larvae's diet is POM.

Taking the string or yarn, cut and tape or glue pieces to connect each animal with its food source. The number of strings connecting each should correspond to a number from 0 to 10. This number is based on your calculations and the formula used on the left. For example, glue one piece of string between POM and young guppies. Do this exercise for both food webs on page 81-82.

Notes: A ruler and pencil may be substituted for string and glue.

FACTivity continues on page 85.







After you have completed both food web circles, take a moment to compare and contrast them. What does each string represent? In the first web, what do you notice about the relationship of algae to the rest of the web? What happens when albizia is introduced into the food web? What are the differences between the two food webs? Answer the question posed at the beginning of this FACTivity. Think about other food webs, such as those in a natural area near you. Do you think the introduction of an invasive plant or animal species could change these other food webs? Why?



Figure 13. Taro growing in a wetland in Waipi'o Valley. Taro has been an important food crop for Hawaiians. Photo by Dr. J. B. Friday.

Water Is Wealth

Water– *Wai*

For early Hawaiians, life revolved around water (*wai*). *Wai* was the source of land and man. It gave life to food, plants, and vegetation. For most Hawaiians, water also produced the staff of life—*kalo* (or taro, a root crop) (**figure 13**). Having an abundance of water on your land demonstrated your wealth. The word *Waiwai* means wealth, prosperity, ownership, possession. Literally it is “water-water.” *Wai* was the possession of no man, even chief (*ali'i*) or king (*mō'i*). Every family that lived on and cultivated the land used a given water source. To have a right to use the water, the family would help to maintain the water source. If the family did not use or help to maintain the water source, they had no right to claim it.

Dividing *Wai–Ahupua'a* System

In old Hawai'i, districts, lands, and lots were subdivided into *ahupua'a*, the chief political system. Each *ahupua'a* stretched from the seashore up into the mountains. Ridges, rocks, stream channels, and sometimes a tree would mark the boundaries. At the seashore of each *ahupua'a*, an altar of rocks (*ahu*) would be placed with a wooden image of a pig (*pua'a*) to mark the boundaries; thus, the word *ahupua'a*. Offerings were also placed on the *ahu* for the rain god or to pay tax to the chief of the *ahupua'a*. This system assured **sustenance** and survival through the exchange and sharing of food, fish, water, firewood, house timbers,

and thatch between the tenants and chief. It also ensured that the land would be cared for from the mountaintops to the sea.

Within the *ahupua'a*, streams or *kahawai* (“the place having fresh water”) ran from the upland forests and below. To the Hawaiian farmer (*mahi'ai*), the *kahawai* was particularly important. Along or below the streams, the farmer would tap into the water by making an irrigation ditch (*'auwai*). The *'auwai* diverted water into his or her taro patch (*lo'i kalo*) (**figure 13**), medicinal herbs, or flower farm. The *ali'i* had a supervisor (*konohiki*) to allocate water fairly and coordinate the building of the *'auwai*.

Law and Water Rights

The law of the land came down to water rights. Law in Hawaiian is *kānāwai*, meaning “belonging to the waters.” This law indicated an equal sharing of water. Inhabitants of each *ahupua'a* depended on the water system. The Hawaiian farmer would take as much water as needed for his farm and then would close the inlet so that the next farmer could take his needed share. Everyone would get their needed share of water, while looking after their neighbors' rights as well, without greed or selfishness. The *ali'i nui* (great chief) of the *ahupua'a* had authority and power but not a “divine right.” Since *wai* was something that belonged to *Kane-i-ka-wai-ola* (the Hawaiian god of water), the *ali'i nui* did not exercise personal authority but instead provided his people with their rights to water and life. *Ali'i nui* who abused this role were at times rejected or killed. These harsh actions demonstrated the importance of rights (*pono*) within the social system.

Streams—Kahawai

The *kahawai* provided not only *wai*, but also food. Hawaiians, most often women (*wahine*), regularly used one-person scoop nets in streams for catching food. The small nets were used to catch crabs, fresh-water shrimp (*'opae*),

and *'o'opu*, a fresh-water fish known for its *ono* (delicious) taste. The branches of the endemic shrub *'ūlei* (*Osteomeles anthyllidifolia*) are easily bendable into a loop. The branches can be lashed together with cord, forming a handle to the net. Fishers also placed traps (*hīna'i*) in the streambed to catch *'opae* and *'o'opu*. The traps were more like baskets and were made from the roots of *'ie'ie* or the vines from the *'āwikiwiki* (*Canavalia galeata*).

Celebrating Water Today

Water remains a valued natural resource in Hawai'i. Hawaiians interested in traditional values joined Hawaiian graffiti artists Estria Miyashiro and John “Prime” Hina in a special project in 2011. Together, they created the third Water Writes mural. The artists painted the Hawaiian mural, which is over 7.5 meters (25 feet) high and 70 meters (200 feet) long, in Honolulu. The mural celebrates the relationship between Hawaiians and water.

Recently students in Hilo, HI, took a field trip to a forested stream. Forest Service scientists taught these students about stream ecology and goby fish found only in Hawai'i (**figure 14**). As a part of a program called FOCUS (Forests, Ocean,



Figure 14. Students learn about goby fish and stream ecology during a field trip. Photo courtesy of Richard MacKenzie.

Climate and Us), the students later painted a mural showing the goby fish in their native environment (**figure 15**). Dennis Taniguchi of the East Hawai'i Cultural Center guided the mural's creation. As is usual for Hawaiians interested in keeping the traditional culture alive,

art is used to celebrate *aloha 'āina*, or love of the land. These two examples, however, show that Hawaiians today also like to celebrate their love of water. Like Hawaiians throughout history, they know that water is wealth.



Figure 15. Detail from the goby mural painted by Hawaiian students.

References

- Handy, E.S.C.; Handy, E.G.; Pukui, M.K. 1991. *Native planters in old Hawaii: their life, lore, and environment*. Honolulu, HI: Bishop Museum Press.
- Pukui, M.K.; Elbert, S.H. 1986. *Hawaiian dictionary: Hawaiian-English, English-Hawaiian*. Honolulu, HI: University of Hawaii Press.
- Isabella, A.A. 1992. *La'au Hawai'i: Traditional Hawaiian uses of plants*. Honolulu, HI: Bishop Museum Press.

Additional Web Resources

- U.S. Geological Survey food web and its function:**
<http://www.wrcamnl.wr.usgs.gov/isoig/projects/fingernails/foodweb/definition.html> (Contains a link to using nitrogen isotopes)
- Information about albizia trees in Hawaii:**
<http://island-trust.com/albizia-the-tree-that-ate-puna.html>
- Hawai'i Division of Aquatic Resources—Streams:**
<http://hawaii.gov/dlnr/dar/streams.html>
- Hawai'i Division of Aquatic Resources—Cultural Importance of Streams:**
http://hawaii.gov/dlnr/dar/streams_cultural_importance.html
- FOCUS (Forests, Ocean, Climate, and Us) Program:**
<http://www.wylandfoundation.org/education-FOCUS.shtml>
- Water Writes Mural:**
<http://www.nonstophonolulu.com/blogs/the-making-of-estrias-water-writes-mural/>

National Education Standards

National Science Education Standard	Where and How the Standard Is Addressed
Abilities Necessary To Do Scientific Inquiry	Introduction and Introduction Reflection Section: Identify questions, design a scientific investigation. Methods Reflection Section: What the scientists did. Findings Reflection Section and FACTivity: Develop explanations from evidence, think critically. Tables 1 and 2 and FACTivity: Mathematics.
Understandings About Scientific Inquiry	Methods: Finding similar stream areas. Tables 1 and 2 and FACTivity: Mathematics. Thinking About Science, Methods, and figure 11: Technology in scientific inquiry.
Populations and Ecosystems	Thinking About the Environment: Food webs. Introduction, Findings, Findings Reflection Section, Discussion, Discussion Reflection Section, FACTivity: Food webs.
Populations, Resources, and Environments	Introduction: Invasive species introduction (albizia).
Structure of Earth System	Thinking About Science: All living things contain nitrogen. Nitrogen sidebar: Nitrogen and volcanic soils.
Natural Hazards	Introduction: Invasive species introduction (albizia).
Understandings About Science and Technology	Thinking about Science: Using technology to study atoms. Methods and figure 11: Using a ratio mass spectrometer to identify food webs.
Science as a Human Endeavor	Meet the scientists: The human experience of science.
Nature of Science	What kind of scientists did this research? Findings, and figure 12: Significance of results.

National Curriculum Standards for Social Studies	Where and How the Standard Is Addressed
Culture	Water as wealth and Streams— <i>Kahawai</i> : Hawaiian view of water.
People, Places, and Environments	Introduction and figure 2: The introduction of albizia. Water is wealth: Hawaiian view of water.
Power, Authority, and Governance	Dividing <i>wai</i> and Law and water rights: Hawaiian view of water.
Production, Distribution, and Consumption	Dividing <i>wai</i> and Law and water rights: Hawaiian view of water.
Science, Technology, and Society	Thinking About Science, Methods, and figure 11: Ratio mass spectrometer.
Global Connections	Introduction and Methods: Introduction of nonnative species.

Left High and Dry?



Photo courtesy of Dr. Susan Cordell.

***Attempting To
Restore a Tropical
Dry Forest in Hawai'i***

Meet the Scientists



◀ **Dr. Susan Cordell**, Ecologist: My favorite science experience is returning to our tropical dry forest **restoration** experimental plots and seeing native species thrive. A decade ago, most people thought we were crazy to attempt restoration in Hawaiian dry forests. They

believed that fountain grass, a highly **invasive** grass from Africa, would out-compete native seedlings. Fountain grass had already displaced most of Hawaiian tropical dry forests. When we first removed fountain grass in areas where goats were kept out, native species flourished while the fountain grass took a long time to recover. Science allows us to ask questions and challenge ideas and, in this case, we learned that, with a lot of effort, tropical dry forests can be restored.

▶ **Ms. Moana McClellan**, Ph.D. Student: One of my favorite things about working in the Hawaiian tropical dry forests is the chance to learn about **endemic** plant species. These are plants that are found nowhere else. Hawai'i has so many endemic species. One of my favorite experiences working at *Ka'ūpūlehu* was my first encounter with the *'ohe makai* tree; a magnificently beautiful tree that grows out of nothing substantial enough to be called soil. For me, being a scientist gives me the opportunity to ask questions that no one knows the answer to. Then, I get to go out to find the answers.



▲ **Ms. Yvonne Yarber Carter**, Outreach Education Coordinator: Only 5 percent of Hawai'i's dry tropical forest remains. A special science experience was having two different kinds of volunteer groups help with our restoration efforts in the dry forest. We had a group of intermediate students from Hawai'i from a program called *Na Kahumoku*. These students teamed up with a group from Cornell University's Environmental Earth Sciences program. They **mentored** each other. Because *Na Kahumoku* had worked with us many times before, the students had plenty to share about dry forest restoration.

The Cornell students shared science that applied to the restoration. I could feel their excitement about seeing how the trees and shrubs they had planted as seedlings were thriving. That excitement has grown into real commitment, and each year a new Cornell group comes. They measure and record growth data on those trees planted the year before.

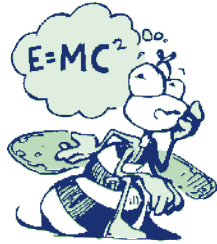
When two groups come together in harmony, the days are filled with *aloha*, learning, hope, knowledge, and being part of change for the better. It feels like we can, one day at a time, heal this dry forest budding up out of the lava. In this photo, I am talking to students about the dry forest of *Ka'ūpūlehu* before working on the land. Photo by Keoki Apokolani Carter.

Glossary words are in **bold** and are defined on page 99. Hawaiian words are in *italics* and their pronunciation is given on page 106.

Be sure to read
“A Hawaiian View
of Dry Tropical
Forests”
on page 102.

Thinking About Science

Sometimes, a research project is viewed as a case study. A case study is a detailed look at one thing as an example of similar things. Consider the experiences of a student who has transferred into a classroom in the middle of the school year. A detailed study of this student's experience may be done as a case study. The findings from such a study would be used as an example of what other students in the same situation may experience.



In the research you are about to read, the scientists studied a special kind of tropical forest in Hawai'i. This kind of forest is **endangered** in Hawai'i and in other **tropical** regions. The scientists wanted to learn how to **restore** this particular forest. They also wanted to share what they learned with other people hoping to restore this type of forest in other places. They hoped that their research would be used as a case study of how to restore this special type of tropical forest wherever it is found.

Thinking About the Environment

The tropical zone of Earth is a band near the Equator (**figure 1**).
[continues on page 93]

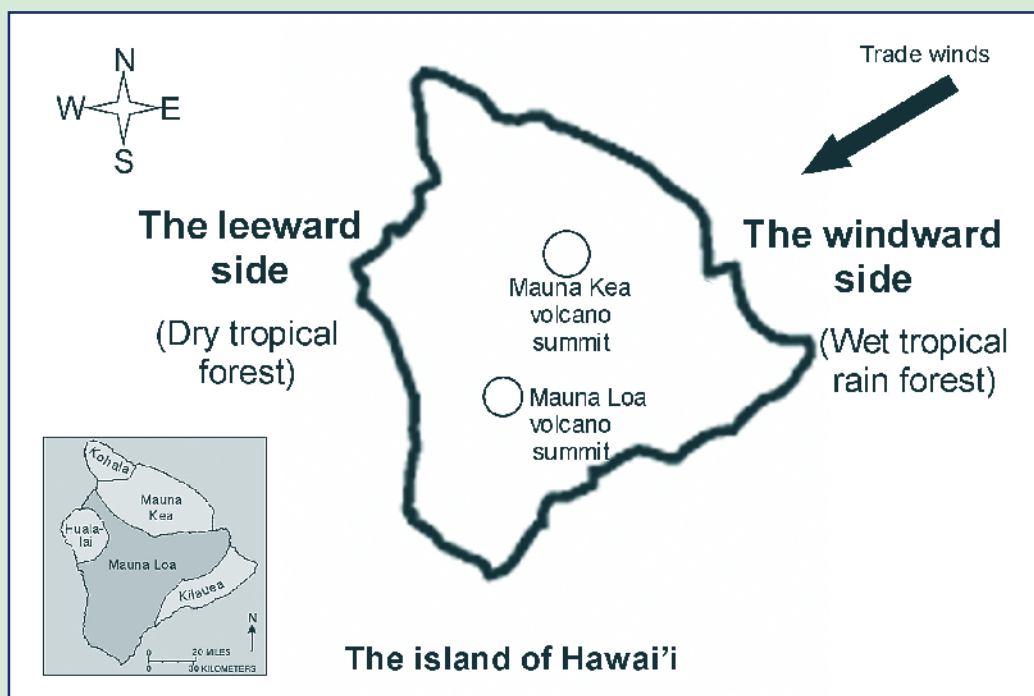


Figure 1. The tropical zone of Earth is an area between the Tropic of Cancer and the Tropic of Capricorn.



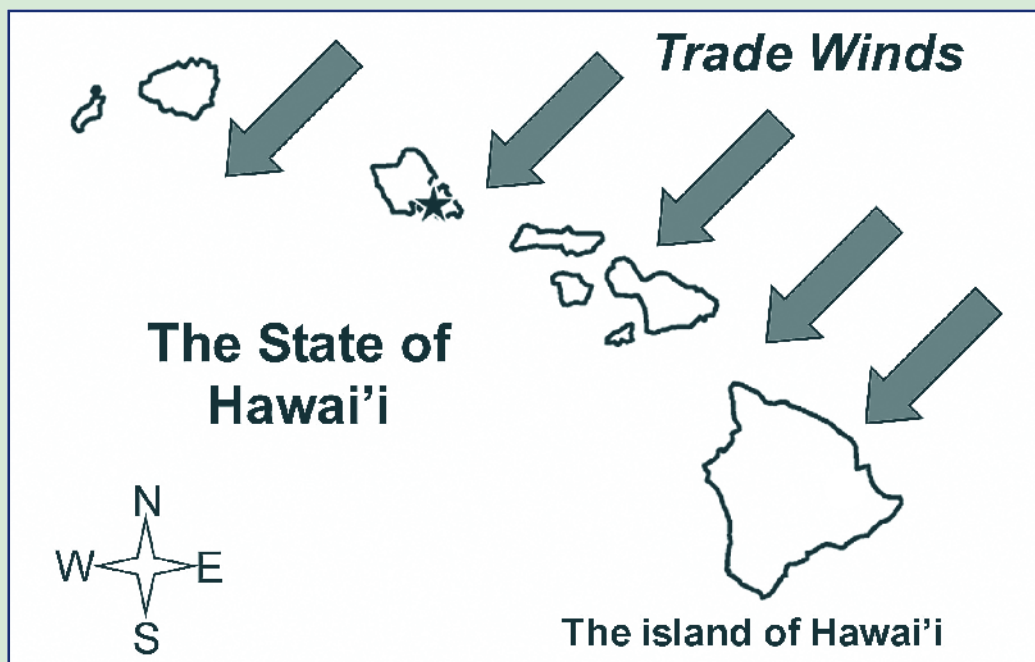
Islands with mountains in the tropical zone usually have two distinct sides (**figure 2**). One side is called the windward side. This side is where the winds coming off of the ocean, known as the trade winds, approach the island. In Hawai'i, the trade winds blow from the northeast to the southwest (**figure 3**). As the wind travels up the mountains, the cooler air causes clouds to

form. This side of the island has a lot of rain. The forests on this side are called tropical rain forests. The other side of the island is called the leeward side. This side of the island has very little rain, because all the moisture has been lost on the windward side. The forests on the leeward side are called tropical dry forests (**figure 4**).



◀ **Figure 2.** The windward and leeward sides of the island of Hawai'i. The inset shows that Hawai'i is a collection of five volcanoes. Most of Hawai'i, therefore, is mountainous. Inset courtesy of the U.S. Geological Survey (USGS), <http://hvo.wr.usgs.gov/maunaloa/>.

Figure 3. Hawaiian trade winds blow from the northeast to the southwest. ▶



What is the tropical zone?

The tropical zone is an area north and south of the Equator that is warm all year. In the tropical zone, the sun is directly overhead at least 1 day during the year. Because the climate is warm, land in the tropical zone is home to more than one-third of Earth's human population. The tropical zone is sometimes called the tropics.

Tropical dry forests are one of the most endangered tropical forests. In the past, people allowed cattle and horses to graze in these forests. Wildfires have destroyed many of the dry forests, and people have cleared them to build homes and for agriculture. Invasive **species** have also come into the dry forests, taking over areas that once had **native** species. The scientists in this study wanted to learn how to restore a dry tropical forest in Hawai'i that was in danger of being lost.



Figure 4. Tropical dry forests have little rainfall.

Introduction

The *Ka'upulehu* dry forest is located on the leeward side of the island of Hawai'i (**figures 5 and 6**). The forest land is owned by *Kamehameha* Schools, which is dedicated to preserving traditional Hawaiian culture through education. This forest, like most tropical dry forests, was in danger of being lost as a native ecosystem. In the past, people had cleared the land for agriculture and had allowed cattle and horses to graze on it.

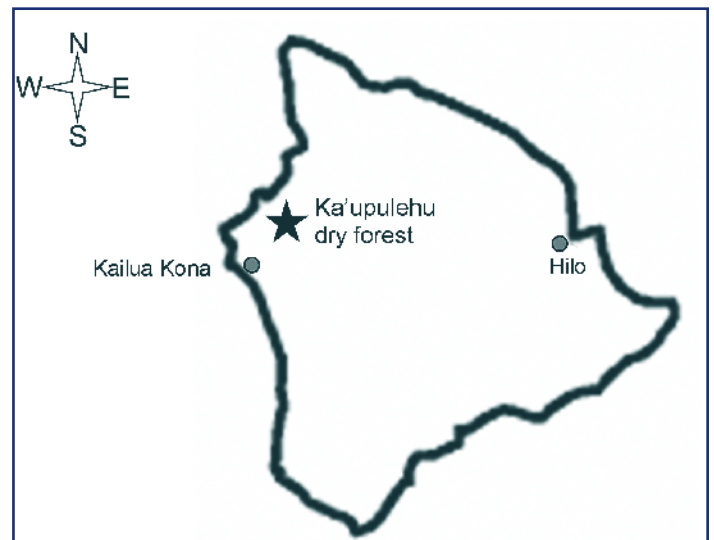


Figure 5. The *Ka'upulehu* dry forest is located at 600 meters **elevation**. It is 25 hectares in size. Average rainfall in the dry forest is less than 750 millimeters per year. Contrast these measurements with rainfall on the windward side of Hawai'i, which is about 3,000 millimeters per year.



Figure 6. The *Ka'upulehu* dry forest on the island of Hawai'i.

Number Crunches

- What is the elevation of *Ka'ūpūlehu* dry forest in feet? Multiply 600 by 3.28 to find out.
- What is the size of *Ka'ūpūlehu* dry forest in acres? Multiply 25 by 2.47 to find out.
- How much rain falls in Hawai'i in inches? Multiply the amount in millimeters by 0.039 to find out.

Reflection Section



- Why do you think it is important to save native ecosystems?
- What is one way to restore a native forest?
- What question did the scientists want to answer? What did the scientists want to do after they answered their question?

Methods

The scientists first placed a wire fence around the *Ka'ūpūlehu* dry forest (**figure 7**). The fence was built to keep cattle and other grazing animals out of the forest. Hawai'i has no native ungulates (**un gə lāts**: mammals with hooves) so the native plants are not adapted to them. Then, the scientists removed as many invasive plant species as they could. When these efforts did not cause the native forest to return, the scientists decided to try something else.

The scientists removed an invasive grass from the forest. This grass was growing thickly along the ground. They removed the invasive grass by first cutting the grass, then applying a chemical to kill it. The scientists collected native seeds from trees and plants in *Ka'ūpūlehu* dry forest and other nearby dry forests. They

Figure 7. A fence kept cattle and other grazing animals out of the dry forest.



planted the seeds in a greenhouse. As each plant grew large enough, the scientists planted it in the forest ground. From 1999 to 2006, the scientists and others planted almost 5,000 plants (**figure 8**).

Type of plant	Number planted
Trees	2,996
Shrubs	997
Vines	237
Herbs	33
Sedges	4

Figure 8. The types and numbers of native plants planted in the dry forest between 1999 and 2006.

When the scientists planted a plant, they attached a tag to it (**figures 9a and 9b**). This tag contained information about the species of plant and when it was planted. The scientists recorded information from each plant on paper and then entered it into a computer. Unfortunately, 625 plants died before their information was recorded. For these 625 plants, the information was lost. All plants were watered for 6 months after planting to encourage their growth.

The scientists counted the number of living and dead plants and trees according to species in every year except 2004.

Number Crunches

- 🍃 What was the total number of native plants planted between 1999 and 2006?
- 🍃 What was the average number of plants planted per year?



Figure 9a and 9b. A tag with information on it was attached to each plant that was planted (9a, top). As the plant grew, the tag remained so that the scientists could track its growth (9b, above).

Reflection Section

- 🍃 Why do you think the scientists wanted to keep track of each plant species and the date of planting?
- 🍃 From this method, could the scientists determine whether it was necessary to kill the grass with a chemical after they had cut it? Why or why not?



Findings

From 1999 to 2003, rainfall was below normal. In 2004, *Ka'upulehu* dry forest had the highest rainfall ever recorded there (1,249 millimeters). In 2005 and 2006, rainfall was considered normal. Of the 4,892 plants and trees planted, 1,487 were still alive in 2007. The scientists found 3,357 dead plants and trees and could not find 48 plants (**figure 10**).

Vines were the most successful type of plant, with a 63-percent survival rate. Only 34 percent of the trees were still living in 2007. The Federal Government listed five of the species planted as **endangered species**. These species represented almost 60 percent of the total surviving plants (**figure 11**).

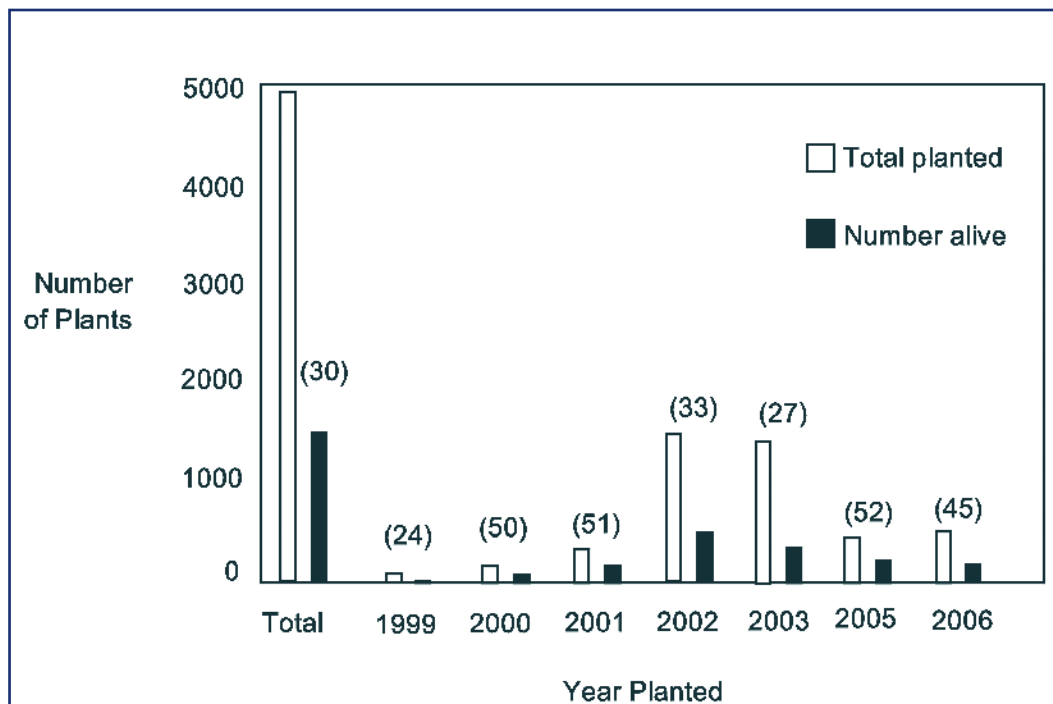


Figure 10. Survival of plants and trees by the year they were planted. The numbers in parentheses represent the percentage of surviving plants.

Scientific name of the endangered plant	Hawaiian name of the plant	Number of plants in the State of Hawai'i before the planting program	Percent increase in the plant population after the planting program
<i>Abutilon menziesii</i>	<i>Ko'oloa'ula</i>	450	22
<i>Bonamia menziesii</i>	<i>No known name</i>	200	75
<i>Caesalpinia kavaensis</i>	<i>Uhiuhi</i>	42	20
<i>Colubrina oppositifolia</i>	<i>Kauila</i>	800	21
<i>Hibiscus brackenridgei</i>	<i>Ma'o hau hele</i>	70	146
<i>Kokia drynarioides</i>	<i>Koki'o</i>	3	9,733
<i>Nothocestrum breviflorum</i>	<i>'Aiea</i>	100	54
<i>Pleomele hawaiiensis</i>	<i>Halapepe</i>	300	99
<i>Sesbania tomentosa</i>	<i>'Ohai</i>	100	3

Figure 11. Increase in Federal endangered plant species as a result of the planting effort. When scientists were planting the plants, three *koki'o* plants were living in the wild. Scientists now believe that no living *koki'o* plants live in the wild in Hawai'i.



Reflection Section

- How is the effect of the drought from 1999 to 2003 reflected in figure 10? How is the year of high rainfall reflected in figure 10?
- Examine figures 10 and 11. Would you say the planting effort was a success? Why or why not?

Discussion

Vines had the highest rate of survival. The scientists believe the vines had a high rate of survival because vines grow quickly and can climb over shrubs and trees. Vines, therefore, receive more sunlight and are able to shade out grasses and weeds. The scientists recommend that future efforts to restore native dry forests begin with planting vines. The vines will shade out invasive grasses and weeds. They will also provide shade for future shrub and tree plantings. The shade should increase the rate of survival for shrubs and trees.

The most important finding from this study is what should be done in the future to help

restore native dry tropical forests. Although fewer plants and trees survived than the scientists had hoped, they learned many things from this project. In the future, they will do a better job of planning how to restore the dry forest. They will do a better job of keeping track of each plant and tree. They will count the surviving plants and trees more frequently, and they will use technology to help them be more accurate and complete in their research. The scientists concluded that this research was a success. It will help them and other scientists do a better job of restoring native dry tropical forests in the future.



Reflection Section

- State in your own words what the most important finding is from this study. How did the scientists determine this finding?
- How can you apply this finding to your own life?

Adapted from Cordell, S.; McClellan, M.; Yarber Carter, Y.; Hadway, L. 2008. Towards restoration of Hawaiian tropical dry forests: the *Ka'upulehu* outplanting programme. *Pacific Conservation Biology*. 14: 279–284. http://www.fs.fed.us/psw/publications/cordell/psw_2008_cordell001.pdf.

Glossary

Aloha (a lō ha): Hawaiian word meaning love, compassion, peace, mercy, or connection. Also used today for both hello and goodbye.

Degraded (dē grā dād): Being in a worse condition than before.

Dense (den(t)s): Marked by compactness or crowding together of parts.

Ecosystem (ē kō sis tēm): A system made up of an ecological community of living things interacting with their environment especially under natural conditions.

Elevation (el ə vā shən): Height above sea level.

Endangered (en dān jərd): Being in danger or peril.

Endangered species (en dān jərd spē sēs): A species of animal or plant in danger of becoming extinct or dying off.

Hardwood (hārd wud): The wood of a tree without cones.

Invasive species (in vā siv spē sēs): A plant or animal species not native to an area and with the potential to harm the native environment.

Mentor (men tōr): To tutor or to teach.

Native (nā tiv): Plant or animals species living or growing naturally in an environment.

Restoration (res tə rā shən): The act of bringing back to an earlier condition.

Restore (rē stōr): To bring back to an earlier or normal condition.

Tropical (trāp ə kəl): Of, in, or like the tropics, a region of Earth close to the Equator.

Accented syllables are in **bold**. Definitions and marks are from <http://www.merriam-webster.com>.

FACTivity



Time Needed

1 class period.

Materials

- “Left High and Dry” article, one for each pair of students (or one per student).

The question you will answer in this FACTivity is: If people are able to restore **degraded** ecosystems, is it acceptable to destroy them for our temporary use?

You will answer this question by doing a case study. See “Thinking About Science” for information about case studies. First, read the background information below for this case study. Then, follow the procedure for small group debate and class discussion.

Background

There is a small island off of the coast of the Southeastern United States that is protected by a shore protection law. This law protects the beach and sand dunes of the island. Signs warn visitors not to walk on the dunes, and visitors can be fined if they do so.

The sand dunes are home to millions of species of plant and animal life. They form a natural buffer and protect upland homes, hotels, and other buildings from the tides, winds, waves, and storms. Morning glory vines, ghost crabs, sea gulls, Spanish bayonets, and sea oats all make their home in and around the sand dunes. Many shorebirds lay eggs directly on the sand in the dune area. Even the threatened loggerhead turtles come ashore during the summer months to lay their eggs in the warm sands. The dunes are extremely fragile, and the plants that hold the sand in place are easily killed by foot traffic. All of these communities are protected by the law. It is the goal of the people that own the island to promote the preservation of these natural habitats.

Recently, however, the people responsible for the island allowed a large film company to use almost 5 acres of the island's sand dunes to film an action movie. The movie set had to look like it was in a tropical location. The island is located just north of the tropical zone. To make the dune area look tropical, the existing dunes had to be changed. The film company covered the existing dunes with 4 feet of new sand, covering all the plants and animals living there. They used trucks and machines to create a brand-new dune area. They brought in palm trees from a tropical area and planted them in the new sand.

The people responsible for the area said that it was okay to allow the film company to destroy the existing sand dunes. They made this decision because the film company said they would restore the sand dunes to their original condition when they finished filming. The people responsible for the area said the film company might even make the area better

than it was before because some invasive plant species had been growing on the dunes.

Members of a citizens' organization that opposed the change to the existing dunes said that no one had documented what the existing area was like before the film company changed it. Because of lack of evidence, no one knew exactly what they had changed. The citizens' organization did not like the fact that plants and animals had been covered with new sand in a protected area, and that the people responsible for the area did not respect a law intended to protect the dunes.

Method

For this case study, your teacher will divide the class into groups of four students. Two students in each group will take the managers' position that the destruction of the dunes was acceptable, as long as the film company agreed to restore the area. The other two students will take the citizens' position that just because a fragile natural area that is protected by law can be restored, that does not mean it should be destroyed in the first place. With your partner, you should spend 10 minutes thinking about your position and writing out your argument. Then, debate and discuss your position with the other group.

Thinking about this case study and about the restoration of the tropical dry forest, answer the question posed at the beginning of this FACTivity. In a class discussion, consider the restoration of degraded ecosystems. What is similar and different about the restoration of the dry tropical forest and the sand dunes? From these two case studies, what can your class conclude about ecosystem restoration?

Another FACtivity



Using the figure below, calculate the number of endangered plants that survived the *Ka'ūpūlehu* planting program and then calculate the total number of endangered plants of each species growing in Hawai'i. Pretend that you are in charge of taking care of endangered species across Hawai'i following this planting program. Which species would be the most important and why? Discuss your decision in a classroom discussion.

Scientific name of the endangered plant	Hawaiian name of the plant	Number of plants in the State of Hawaii before the research	Percent increase in the plant population after the planting program	Number of plants that survived the planting (Number of plants before times the percent increase; remember the decimal)	Number of plants in the State after the planting program
<i>Abutilon menziesii</i>	<i>Ko'olua'ula</i>	450	22		
<i>Bonamia menziesii</i>	<i>No known name</i>	200	75		
<i>Caesalpinia kavaiensis</i>	<i>Uhiuhi</i>	42	20		
<i>Colubrina oppositifolia</i>	<i>Kauila</i>	800	21		
<i>Hibiscus brackenridgei</i>	<i>Ma'o hau hele</i>	70	146		
<i>Kokia drynarioides</i>	<i>Koki'o</i>	3	9,733		
<i>Nothocestrum breviflorum</i>	<i>'Aiea</i>	100	54		
<i>Pleomele hawaiiensis</i>	<i>Halapepe</i>	300	99		
<i>Sesbania tomentosa</i>	<i>'Ohai</i>	100	3		

To read about a tropical dry forest in Puerto Rico, see "Some Things Will Always Change" in the Tropical Forest edition of the *Natural Inquirer* (<http://www.naturalinquirer.org>). What are some of the similarities and differences between these two tropical dry forests?

A Hawaiian View of Tropical Dry Forests

The Hawaiian dry forest was valued in the past for its essential natural resources. The forest was especially prized for its **hardwood** trees. The area where these forests grew had intense heat and a dry atmosphere and landscape. Native plants, therefore, grew slowly. Because of this slow growth, the rings of the tree were close together, creating a strong and durable wood product. The wood of some of these trees was so **dense** it would sink.

Traditional Hawaiian ceremonies make use of the vines and trees growing in tropical dry

forests of Hawai‘i, such as for *leis* and for *hula*. A *lei* is a necklace that is made from bone, seeds, leaves, flowers, or vines. The best known *leis* today are made from flowers. *Leis* are a symbol of love, connection, or respect. *Hula* is the traditional dance of Hawaiians. It includes chants and traditional musical instruments. **Figure 12** shows the uses of just four of the important trees of Hawaiian dry forests.

Before so many people moved to Hawai‘i over the past few hundred years, dry forests

Latin name and status	Hawaiian name, common name, and meaning	Traditional use
<i>Diospyros sandwicensis</i> Endemic: Found only in Hawai‘i	<i>Lama, Elama</i> Hawaiian ebony, Hawaiian persimmon, enlightenment	<i>Lele</i> (platform above a wooden altar), <i>ho’okupu</i> to <i>Lono</i> (offering to one of the four main <i>akua</i> , or gods), placed at <i>kuahu</i> (<i>hula</i> alters), <i>pī’oi</i> (edible fruit), <i>pupupu hale</i> (huts constructed from <i>lama</i>) were used as a healing place.
<i>Psydrax odorata</i> Native	<i>Alahe’e, Ohe’e, Walah’e</i>	<i>ō’ō</i> (digging stick for gardening), fragrant flowers or seeds used in <i>lei</i> , leaves used for black dye for <i>kapa</i> (clothes or bed clothes made from bark of native plants), <i>‘au ko’i</i> (adze handles; handles for a tool used to cut wood), <i>kao</i> (fishing spears), <i>makau</i> (fish hooks) and <i>ko’i</i> (adzes), <i>ama</i> (outrigger float)
<i>Dodonaea viscosa</i> Native	<i>‘a’ali’i</i> , Hawaiian hopseed bush A reference to the people of <i>Ka’ū</i> , <i>‘a’ali’i</i> , standing in the wind	Seeds boiled to make red <i>kapa</i> dye, fruit and leaves used in <i>lei</i> , crushed leaves provided relief from rashes and contagious diseases, spears for <i>he’e</i> (octopus), bait stick.
<i>Erythrina sandwicensis</i> Endemic	<i>Wiliwili</i> Hawaiian coral tree, tiger’s claw	<i>Olo</i> (large surfboard for nobility), fishing gear containers, seeds produced permanent <i>lei</i> , flowers for <i>lei</i> .

Figure 12. Some trees of Hawaiian dry forests.

could be found in all the leeward coastal areas of the islands. Today, only a small percentage of tropical dry forest land is left in Hawai‘i.

Throughout time, Hawaiians have viewed the island’s natural resources as a source of wealth. Native Hawaiians express their kinship with all life through their respect for natural resources. The *lama* tree, for example, is recognized as a *kinolau*, the physical form of *Lono*, one of the four main Hawaiian gods (**figure 13**). The *lama* tree, therefore, is sacred to Native Hawaiians. Notice the uses of the *lama* tree in the figure on page 102.

Hawaiians today recognize the importance of dry tropical forests.

“Left high and dry” was first used to refer to a ship that was beached. It is now used to indicate that someone or something has been left stranded or abandoned.

As you read in this article, Hawaiians are taking steps to restore these valuable forests. In some communities, this restoration has become a community celebration. Take a look at the flower mural that serves as the background of the journal cover and is found at the beginning of this article. This mural was painted by Hawaiians age 7 to 60 who care about the dry tropical forests of Hawai‘i. They have used their *aloha* to create a mural to celebrate and learn about dryland forests.



Figure 13. Lama tree. Photo by Dr. J.B. Friday.

Additional Web Resources

Hawaiian dryland forests—Can they be restored?
<http://www.hawaiiforest.org/reports/dryland.html>

Tropical dry forests of the Pacific—Hawaiian Islands:
<http://www.geog.ucla.edu/tdfpacific/hawaii.html#bigisland>

Slideshow of Hawaiian dryland native plants:
<http://www.drylandforest.org/home-slideshow-dryland-natives>

Native dryland trees and their flowers:
<http://www.drylandforest.org/native-dryland-trees-their-flowers>

National Geographic Kids—Hawai‘i Tropical Dry Forests:
<http://www.nationalgeographic.com/wildworld/profiles/terrestrial/oc/oc0202.html>

References:

<http://www2.hawaii.edu/~eherring/hawnprop/dio-sand.htm>
http://nativeplants.hawaii.edu/plant/view/Diospyros_sandwicensis

National Education Standards

National Science Education Standard	Where and How the Standard Is Addressed
Abilities Necessary To Do Scientific Inquiry	Introduction: A research question asked to address a problem. Introduction Reflection Section: Articulating a research question. Methods: What the scientists did before collecting data, the use of tags to keep track of plants (also figures 9a and 9b), data collection (counting). Methods Reflection Section: Importance of recordkeeping, are data sufficient to draw a conclusion? Figure 10: Drawing conclusions from data. Findings Reflection Section: Interpreting data and drawing conclusions. Discussion: The importance of planning future studies. Discussion Reflection Section: Communicating findings.
Understandings About Scientific Inquiry	Meet the Scientists: Scientists get to answer new questions. Thinking About Science: Case studies. Introduction: Research is done to solve problems. Introduction Reflection Section: The importance of keeping track through tagging plants. Methods: The loss of information because of poor recordkeeping. Figures 9a and 9b: Record keeping. Methods Reflection Section: Importance of recordkeeping. Discussion Reflection Section: Application of science to one's own life.
Populations and Ecosystems	Thinking About the Environment: Dry tropical forests and invasive species. Introduction Reflection Section: The importance of protecting ecosystems.
Structure of Earth System	Thinking About the Environment: The tropical zone, trade winds, and tropical forest types. Figures 1–5: Geographic features of Hawai'i. What is the tropical zone?: The tropical zone.
Populations, Resources, and Environments	Thinking About the Environment: Human destruction of native dry forests. What is the tropical zone?: Human population in the tropical zone.
Natural Hazards	Thinking About the Environment: Wildfires and dry forest destruction.
Risks and Benefits	Thinking About the Environment: People benefitted from grazing but risked the destruction of the dry forest.

Science and Technology In Society	Entire article: Student scientists gaining enthusiasm and commitment as a result of scientific work. Discussion Reflection Section: Applying results to own life.
Science as a Human Endeavor	Meet the Scientists: Science as a favorite experience. Discussion Reflection Section: Applying scientific findings to one's own life.
Nature of Science	Meet the Scientists: Proceeded even though some thought their ideas would not work. Discussion: Scientists make mistakes and learn from them for the future.

National Curriculum Standards for Social Studies	Where and How the Standard Is Addressed
Culture	A Hawaiian View of Tropical Dry Forests: Past cultural uses.
People, Places, and Environments	Meet the Scientists: People helping the environment. A Hawaiian View of Dry Tropical Forests: Historic and contemporary value of dryland forests.
Global Connections	Meet the Scientists: Outreach with college students. Thinking About Science: Research may be used in other areas of the tropics. FAC-Tivity: Case study in Georgia.
Production, Distribution, and Consumption	A Hawaiian View of Tropical Dry Forests: Using dryland forest products for ceremonies and other uses.
Civic Ideals and Practices	FACTivity: How should we treat our commonly held natural resources?

The Hawaiian Language and Hawaiian Glossary

The Hawaiian language was an oral language until the early 1800s. Western missionaries created a written Hawaiian language in 1820. The Hawaiian language has eight consonants and five vowels. The consonants H, K, L, M, N, and P are pronounced like English consonants. W is sometimes pronounced “V” and sometimes “W,” depending on which vowel it follows. Hawaiian syllables usually have only one or two letters each, including the ‘okina (ō kē na).

The vowels are usually (but not always) pronounced in this way:

A: As in ah

E: A as in skate

I: E as in meet

O: As in over

U: As in moon

Pronunciation marks used in the glossary below:

ā ē ī ō ū: As in skate, meet, light, over, use

ow as in owl

oo as in moon

Special characters in the Hawaiian language:

‘Okina: The ‘okina is one of the eight consonants in the

Hawaiian language. It represents a glottal stop, like the quick stop you make in the word, “oh-oh.” The ‘okina is usually typed as a backwards single quote mark on computers that do not have Hawaiian fonts.

Kahakō: Each of the Hawaiian vowels can be written with a kahakō (ka ha kō), which slightly changes the way the vowel is pronounced. A kahakō is the bar over a vowel, as the “o” in kahakō. The vowel is pronounced as it is without the kahakō except that its sound is held just a little longer.

The ‘okina and kahakō are important. If either is missing from a word, the pronunciation, as well as the word’s meaning, will change.

As with many languages, one word can have many meanings in the Hawaiian language. The word’s meaning depends on how it is being used and to what it refers, often called its context. Think of the English word “cool.” When it is being used, you automatically know whether it is referring to the temperature or to the attractiveness of something. In the Hawaiian glossary below, you will notice that many words have more than one meaning.

For more information about the Hawaiian language, visit <http://www.instanthawaii.com/cgi-bin/hawaii?Language>. A Hawaiian dictionary can be found at <http://wehewehe.org/gsd12.5/cgi-bin/hdict?!=en>.

Fun words to use in class

Hawaiian	Pronunciation	English
‘aka‘aka, ‘aka	ah ka ah ka	Laughter, mirth, merriment, ridicule, laugh
‘awe	ah vā	Backpack, to carry on back
a‘ole	ah o lā	No
‘a‘ole pilikia	ah ol lā pē lē kē ah	No problem
‘ae	ī	Yes
alaka‘i	ah la ka ē	Leader
aloha	ah lō ha	Hello, goodbye, love, peace, care, etc.
haumana	how ma na	Student
hoo‘olu‘olu, hoo‘olu, ho‘ole‘a, ho‘ohoihoi	hoo ō loo ō loo	Please
hoaloha	hō ah lō ha	Friend, beloved companion
hoa kula	hō ah koo la	Classmate

Hawaiian	Pronunciation	English
hoa pili	hō ah pē lē	Close, intimate, or personal friend
kaikamahine	ka (ē) ka ma hē nā	Girl, daughter, niece
keiki kāne	kā kē ka nā	Boy, son, nephew
kumu	koo moo	Teacher, model, guide, example, base, foundation, root, source, reason, flock, herd, etc.
mahalo	ma ha lō	Thanks, gratitude, admiration, esteem, respect
mahalo nui loa	ma ha lō nū ē lō ah	Thanks very much
makana	ma ka na	Gift, award, reward, donation
makuahine	ma koo ah hē nā	Mother, aunt, female cousin or relative of parents' generation
makuakane	ma koo ah ka nā	Father, uncle, male cousin of parents' generation
mana'o	ma na ō	Thought, opinion, intention, meaning, desire, estimate, anticipate, suppose, mediate, deem, consider, etc.
pilialoha	pē lē ah lō ha	Friendship, loving association, relative, romance
pōmaika'i	po mī kī ē	Good luck, prosperity, benefits, improvement (pertaining to property)

From the journal

‘aiea	ī(ē) ā ya	Shrub and tree species
‘a‘ali‘i, ‘a‘ali‘i ku makani	ah ah lē ē	Medium sized shrub, <i>Dodonaea viscosa</i>
‘āina	ī na	Land
‘akiapōlā‘au	ah kē ah pō la ow	Rare Hawaiian honey creeper, <i>Hemignathus munroi</i> , commonly known as Swiss army beak bird due to its ability to manipulate its beak; occupies woodpecker habitat
‘apapane, ‘akakane	ah pa pa nā, ah kah ka nā	A Hawaiian honey creeper, <i>Himatione sanguinea</i>
‘au ko‘i	ow kō ē	Adze (Ax) handle
‘auwai	ow vī	Irrigation ditch, canal
‘āwikiwiki	ah vē kē vē kē	Vine species
‘ihi	ē hē	Respect
‘i‘iwi	ē ē wē	Scarlet honey creeper, <i>Vestiari coccinea</i>

Hawaiian	Pronunciation	English
‘ie‘ie	ē ā ē ā	Wet forest vine species, <i>kinolau</i> (physical embodiment) of the goddess <i>Laka</i>
‘io	ē ō	Hawaiian hawk
‘ohai	ō ha ī	Shrub species
‘ohana	ō ha na	Family connections; kinship with other life forms
‘ohi‘a	ō hē ah	Tree species
‘o‘o	ō ō	Digging stick
‘ō‘ō	ō ō	Bird species
‘o‘opu	ō ō poo	Fish
‘okina	ō kē na	Pronunciation guide for a glottal stop
‘ono	ō nō	Delicious
‘opae	ō pī	Fresh water shrimp
‘ūlei	oo lā	Sprawling woody shrub, rose family
a‘lahe‘e, walahe‘e	ah la hā ā, wah la hā ā	Shrub species
ahu	ah hoo	Alter, heap, pile, cape, cloak
ahupua‘a	ah hoo poo ah ah	Land division usually running from the mountains to the sea, demarked by an <i>ahu</i> (alter) surmounted by the image of a <i>pua‘a</i> (pig)
akua	ah koo ah	God, spirit, natural element, interacting ecosystems
alaia	ah la ya	Traditional surfboards
ali‘i	ah lē ē	Chief, chiefess (chieftess), officer, ruler, monarch, aristocrat, commander
ali‘i nui	ah lē ē noo ē	Great chief, high chief
aloha	ah lō ha	Hello, goodbye, love, peace, care, etc.
ama	ah ma	Outrigger float
E ola ke koa.	ā ol la kā kō ah	“Live a long time, like a koa tree.”
ha‘aha‘a	ha ah ha ah	Humility
Hahai no ka ua i ka ulaula‘ua.	ha ha ē no ka oo ah ē ka oo la oo la oo ah	“The rain always follows the forests.”

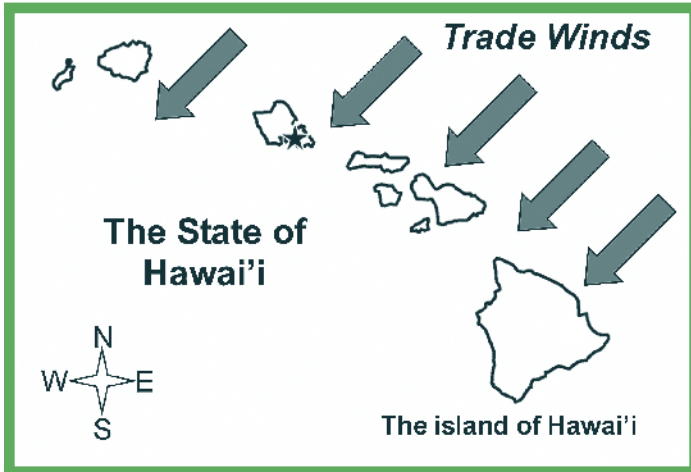
Hawaiian	Pronunciation	English
hala pepe	ha la pā pā	Native tree, <i>Dracaena pleomele</i> , lily family
halau wa'a	how la va ah	Canoe club
hāpu'u	ha poo oo	Tree Fern, <i>Cibotium glaucum</i>
he'e	hā ā	Octopus, slide
hīna'i	hē nī ē	Fish trap or fish trap made from braided 'ie vine, <i>Pandanus</i> (palm-like trees or shrubs), or other material (traditionally used for shrimp, eels, etc.)
Hoe a hoe ka Wa a a me He e nalu i ka waa kahiko.	hoy ah hoy kah va ah ah mā heh eh na loo ē ka va a ka hē ko	"Canoeing and surfing in ancient Hawai'i."
holomoana	hō lō mō ah na	Traveling over long distances or voyaging
ho'okupu	hō ō koo poo	Offering, to grow, sprout, to increase
hula	hoo la	Traditional dance
iako	ya kō	Two wooden bars that attach the outrigger to the canoe
Ka'ūpūlehu	ka ū poo lā hoo	Area in western area of the island of Hawai'i
kahawai	ka ha vī	Stream
kalai wa a	ka lā va ah	The carving and shaping of wooden canoes
kalo	ka lō	A root crop, taro
Kamehameha	ka mā ha mā ha	Large school system on Hawai'i (Statewide), paramount chief that united Hawai'i
kānāwai	ka na vī	Law, code, rule, rule, stature, ordinance
Kane-i-ka-wai-ola	ka nā ē ka vī o la	Water god, water cycles, water exchange, layering of water by temperature
kao	kow	Fishing spear
kapa	kuh pa	Clothes or bed clothes, blanket
kauila or kauwila	ka wē la	Dryland forest tree species, one of the densest Hawaiian trees, lightning
Kilauea	kē la wā ah	Volcano in southeast of the island of Hawai'i
kinolau	kē nō low (ow as in owl)	Physical manifestation of <i>akua</i> , <i>kupua</i> , or <i>kupu</i> (varying levels of gods and supernatural beings)
kīpuka	kē poo ka	Forested island surrounded by hardened lava

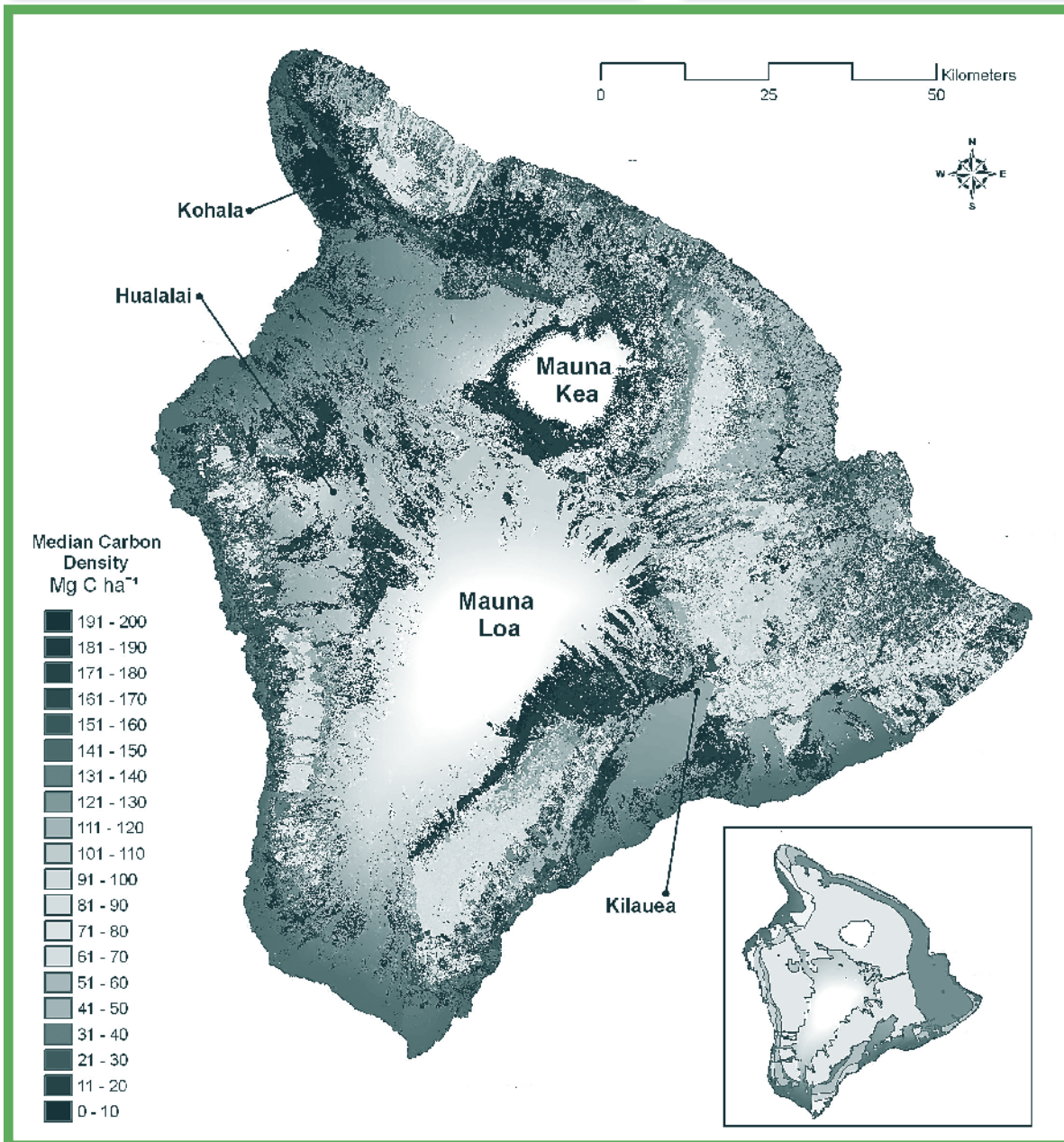
Hawaiian	Pronunciation	English
ko'i	kō ē	Adzes (Axes)
ko'oloa'ula	kō ō lō ah oo la	Plant species
koa	kō ah	Tree species whose wood is used to build canoes and many other wood products
koki'o	kō kē ō	Shrub species
konohiki	kō nō hē kē	Supervisor of water rights; individual who manages land and water resources in an area
kuahu	kū ah hū	Alter
kua'aina	kū ah ī na	Someone who keeps native Hawaiian cultural practices
kupono	kū pō nō	Righteousness
kūpuna	kū pū na	Elders
lama, elama	la ma, ā la ma	Ebony tree
laulima	low lē ma (ow)	Many people working
Laupahoe	la pa hoy hoy	Community and school in the northeast of the island of Hawai'i; Ahupua'a located in the Hamakua district
lei	lā	Necklace made of natural materials
lele	lō lō	Platform above an <i>ahu</i> , acts as a wooden alter that is an extension located above the <i>ahu</i>
lo'i kalo	lō ē ka lō	Wetlands created for a taro patch
lokahi	lō ka hē	In unison
Lono	lō nō	One of four main gods, reigns over Hawaiian agriculture
ma'o hau hele	ma ō ha ō hel ā	Plant species
mahalo	ma ha lō	Thanks; thanksgiving
mahi'ai	ma hē ī	Farmer
makau	ma (ka-ō)	Fish hooks
mālama 'aina	ma la ma ī na	Care for the land

Hawaiian	Pronunciation	English
Mauna Kea	mow na kā ah (ow)	Volcano in the north-central area of the island of Hawai‘i
Mauna Loa	mow na lō ah (ow)	Volcano in the south of the island of Hawai‘i
mililani	mē lē la nē	Praise
mō‘ī	mō ē	King
Na Kahumoku	na ka hoo mō koo	A certain education program
nēnē	nənə	The Hawaiian State bird
ohe makai	ō hā ma kī	Tree species
oli	ō lē	Chant
olo	ō lō	Large surfboard for nobility
ōma‘o	ō ma ō	Bird species
pī‘oi	pē oy	Edible fruit
pono	pō nō	Right, righteousness, morality, duty, goodness, just, etc.
Pu‘u ‘O‘o	poo oo ō ō	Volcano in the southeast of the island of Hawai‘i; current house of Pele, goddess of fire, wind, lightning, and volcanoes
pua‘a	pū ah ah	Pig
pupupu hale	poo poo poo ha lā	Temporary huts, house
Uhiuhi	oo hē oo hē	Plant species
wahi kapu	va hē kuh pū	Sacred
wahi pana	wa hē pa na	Sacred place
wahine	wa hē nā	Woman, women
wai	vī	Water, spirit, liquid, honey
Waipi‘o	vī pē ō	Valley in northeast Hawai‘i (On the island of Hawai‘i)
waiwai	vī vī	Wealth (water water), abundance of resources
wiliwili	wil ē wil ē	Tree species

Eye Witness!

Each of the following appeared in one of the articles in this journal.
Explain what each of these means. You may write your explanation
or hold a class discussion.





Hawai'i-Pacific Islands Crossword Puzzle



Across

2. A place that provides shelter or protection.
4. Hawaiian word for "land."
7. The act or process of clearing forests.
12. Free from error.
13. Popular musician who plays a koa wood guitar.
16. Differing from one another.
17. Living or growing naturally in a particular region.

18. Found especially and often only in a certain locality or region.
20. Present in every living thing.
22. Hawaiian word for "water."

Down

1. Easily affected.
3. Having to do with ecology.
5. Hawaiian word meaning love, compassion, peace, mercy, hello, and goodbye.

6. To bring back to an earlier or normal condition.
8. The height above sea level.
9. A type of salt-water forest found in the tropics.
10. A class of individuals having common characteristics and designated by a common name.
11. The pattern of consumption in an ecosystem.

14. An area north and south of the equator that is warm all year.
15. Forested island in a sea of hardened lava.
19. A measure of tree size.
21. A special mark in the Hawaiian language to aid in proper pronunciation.

Note to Educators

The Forest Service's mission is to sustain the health, diversity, and productivity of the Nation's forests and grasslands to meet the needs of present and future generations. For more than 100 years, our motto has been caring for the land and serving people. The Forest Service, U.S. Department of Agriculture (USDA), recognizes its responsibility to be engaged in efforts to connect youth to nature and to promote the development of science-based conservation education programs and materials nationwide.

The *Natural Inquirer* is a science education resource journal to be used by students in grades 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 middle-school students. 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 teaching about ecology, the natural environment, and natural resources. In this edition of the *Natural Inquirer*, you will find five science articles about Hawai'i and one about the Federated States of Micronesia written in the scientific method format.

The Format of a Natural Inquirer Article

Each *Natural Inquirer* article follows the same format. Each *Natural Inquirer* article is written directly from a published science article, and the scientist who wrote the scientific article has reviewed the *Natural Inquirer* article for accuracy. Each article contains the following sections, which you may introduce to your students as they read:

Meet the Scientists: Introduces students to the scientists who did the research. This section may be used in a discussion about careers in science.

Thinking About Science: Introduces something new about the scientific process, such as a scientific habit of mind or procedures used in scientific studies.

Thinking About the Environment: Introduces the environmental topic being addressed in the research.

Introduction: Introduces the problem or question being addressed by the research.

Methods: Describes the methods used by the scientists to collect and analyze their data.

Findings: Describes the results of the analysis.

Discussion: Discusses the findings and places them into the context of the original problem or question.

Reflection Section: Presents questions aimed at stimulating critical thinking about what has been read or predicting what might be presented in the next section. These are placed at the end of each of the main article sections.

Number Crunches: Presents an easy math problem related to the research.

Glossary: Defines potentially new scientific or other terms to students. The first occurrence of a glossary word is **bold** in the text. A Hawaiian glossary is also provided in this journal. This glossary will help you to correctly pronounce the Hawaiian words.

Citation: Gives the original article citation with a Web link to the original article.

FACTivity: Presents a hands-on activity that emphasizes something presented in the article.

National Education Standards and Evaluations

In the back of the journal, you will find a matrix that enables you to identify articles by the National Science Education Standards and National Curriculum Standards for Social Studies that they address. Each article also contains a list of the standards addressed. Evaluation forms for both educators and students are available on our Web site. We welcome any feedback, so please visit <http://www.naturalinquirer.org> and complete the online evaluation forms. In addition, you may contact Dr. Barbara McDonald at the address below with any comments you have.

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(Please put "Educator Feedback" in the subject line)

Educator Resources

Visit the *Natural Inquirer* Web site at <http://www.naturalinquirer.org>.

From this site, you can order more editions and read and download lesson plans, word games, and other resources to help you use the *Natural Inquirer* in your classroom. You can also view and download a year-long lesson plan aimed at helping your students learn about the scientific process.

Lesson Plan

Note: This generic lesson plan can be used with any article in this edition or with any *Natural Inquirer* article. Using the same plan is possible because each *Natural Inquirer* article follows the same format (See Note to Educators, page 115). A lesson plan for the Hawaiian cultural essays follows.

If students have not yet been introduced to the *Natural Inquirer* and the written scientific format used by scientists, spend 5 minutes on this topic. Below is a sample introduction:

Just as you know the general format of a book or of a Web site, scientists use a particular format when they write up their research. This format usually follows the process they used when they did their study. Because this format is widely used, other scientists know what to expect when they read a scientific paper. Think about the format of a Web site. If you go to a new Web site that has the elements and format that you expect, you can much more easily understand how to search the Web site and find what you want to know. Scientists are able to do the same thing when they read the papers of other scientists.

The *Natural Inquirer* is a science journal that was written at your reading level. It was written directly from research papers that were written by scientists. Because of this, the *Natural Inquirer* follows the same format as the actual scientific paper and it includes additional sections to help you better understand what you are reading. The heart of a scientific paper has four sections: Introduction, Methods, Findings, and Discussion.

- Introduction: Introduces the problem or question the scientists addressed.
- Methods: Presents the methods used by the scientists to collect and analyze their data.
- Findings: Presents the results of the research.
- Discussion: Places the findings into the context of the original problem or question.

The extra sections of a *Natural Inquirer* article:

- Meet the Scientists: This section introduces the scientists whose research is presented.
- Thinking About Science: This section provides one big idea, addressed in the article, about the nature of scientific inquiry.
- Thinking About the Environment: This section provides background information that introduces the topic studied by the scientists.
- Reflection Sections: These are questions placed after the Introduction, Methods, Findings, and Discussion sections to help you think about what you have read.
- Number Crunches: These are easy math problems that provide greater understanding about the research.
- Sidebars: These provide additional information about something in the article.
- Glossary: This section introduces potentially new terms used in the article.

- **FACTivity:** This activity provides a chance for you to become a scientist as you conduct an inquiry or activity related to the article you read.
- **Cultural Essay:** New in this *Natural Inquirer*, this item presents cultural information about Hawai‘i and the Federated States of Micronesia.

Scientific writing is nonfiction. Nonfiction is informational or factual. Although most nonfiction writing does not have a plot, scientific papers come somewhat close to having a storyline. A scientific paper’s format generally follows the process that scientists use to do their research. To better understand a scientific paper, it is best to read it in the order it is presented. You can think of a scientific paper as a factual mystery that unfolds in the four sections outlined previously: Introduction, Methods, Findings, and Discussion sections. Scientists are like detectives who solve scientific mysteries.

Time needed: 1-2 class periods.

Materials needed for each student:

- ***Natural Inquirer* article.**
- **Templates provided on page 118.**
- **Pencil with eraser.**

In this lesson, students will increase their reading comprehension, critical thinking skills, and summarization and explanation skills.

Students will become members of the *Natural Inquirer* Twitter Team, assisting the *Natural Inquirer* with teaching others about their article.

Introduce the *Natural Inquirer* article using the information given above.

Give each student a journal or an article and copies of the template given on page 118. Note that there is room for two Tweets on

each page and students will write up to six Tweets.

Tell students that their job will be to summarize each section of the article. Their summarization will take the form of a Tweet, consisting of no more than 140 characters, including punctuation and spaces. Remind them that as they read each section, they should be thinking about and identifying the most important idea in the section. You may want to read this about Twitter: “At the heart of Twitter are small bursts of information called Tweets. Each Tweet is 140 characters in length, but don’t let the small size fool you—you can share a lot with a little space.” (From <http://www.twitter.com>)

Have each student read their article section by section. This can be done as a class with students taking turns reading out loud, reading in small groups, or silently reading alone.

At the end of each major section, students will take 1-2 minutes to identify the most important idea and 1-2 minutes to write it as a Tweet on the template.

After all sections have been Tweeted, hold a class discussion to share Tweets. Alternatively, have students work in small groups to discuss their Tweets. As a small group, have students develop a single group Tweet for each section. These group Tweets may then be shared with the class in a group discussion.

Extension:

Create a class Twitter account and enter the Tweets on the account. “Friend” the *Natural Inquirer* on Twitter. The *Natural Inquirer* staff will retweet the class Tweets.

Natural Inquirer Tweet Sheet

Article:

Section: _____ Tweeted by: _____

Tweet:

Article:

Section: _____ Tweeted by: _____

Tweet:

Cultural Essay Lesson Plan

Time Needed

30 minutes

Materials

- **Hawaiian Articles Cultural Essays**
(located at the end of the articles).

Introduce the cultural essay by reading the introductory material below. Have students read the cultural essay and answer the questions that follow the introduction.

The introductory material should be used for all articles except “Mangrove Mania.” See “Mangrove Mania” introductory material and questions to the right.

Hawai‘i Background: The Hawaiian Islands were first settled by the Polynesians, who arrived by boat around the year 300 CE (Common Era). The descendants of these first settlers are considered Native Hawaiian. Over time, other groups settled in Hawai‘i, including Europeans, North Americans, Chinese, and Japanese, among others. Today, only about 10 percent of the population is identified as Native Hawaiian.

Native Hawaiian culture, like most ancient cultures, held nature in high esteem. Aware of their dependence upon the natural environment for shelter, food, and clothing, Native Hawaiians developed political and cultural systems to ensure their survival.

In the cultural essay that you will read, you will search for clues to the Native Hawaiian connection with nature. Do this by answering the questions below:

- Who is the essay about?
- What is unique about the place being described?
- How did the place influence what happened?
- Could or did this happen in other places? Why? If so, where and describe how.
- What clues tell you that early Hawaiians respected their natural resources?
- What clues tell you that Hawaiians today respect their natural resources?
- How does the cultural essay relate to the article?
- Name two lessons we can learn from Hawaiian culture.
- Write a list of the lessons identified by the class.

- **Mangrove Mania Essay**
(located on p. 52).

Introductory material: The Federated States of Micronesia, or FSM, was settled up to 3,000 years ago by explorers from Asia and Polynesia. Because the nation’s more than 600 islands are separated by wide expanses of ocean, the culture of each inhabited island has remained distinct from other islands. For example, streams on the island of Pohnpei are inhabited by a freshwater eel. Pohnpeians believe that the streams and rivers were carved out of the land by these eels moving back and forth in the streams and are considered sacred animals. However, on Kosrae Island, only 300 miles away, eels are considered a delicacy and served at special occasions. The people of FSM, however, have things in common. The primary livelihoods across FSM are farming and fishing, and all FSM citizens practice singing, dancing, and storytelling.

Citizens of FSM value their identity as members of distinct ethnic groups with diverse cultural traditions and values. This sense of “unity in diversity” is embedded in the preamble to the FSM constitution: “To make one nation of many islands, we respect the diversity of our cultures. Our differences enrich us. The seas bring us together, they do not separate us. Our islands sustain us, our island nation enlarges us and makes us stronger.” (From <http://www.everyculture.com/Ma-Ni/Federated-States-of-Micronesia.html>.)

In the cultural essay that you will read, you will search for clues to the native connection with nature. Do this by answering the questions below:

- Who is the essay about?
- What is unique about the place being described?
- How did the place influence what happened?
- Could or did this happen in other places? Why? If so, where and describe how.
- How does the cultural essay relate to the article?
- Name two lessons we can learn from these Pacific Islanders.
- Write a list of the lessons identified by the class.

Reflection Section Answer Guide

Treasure Islands

Introduction

- **Why do you think the scientists were interested in learning about the habitat of native and nonnative bird species in Hawai‘i? If you need a hint, reread “Thinking About the Environment.”**

Out of 113 species endemic to Hawai‘i, only 42 exist today. Of the 42, only 11 are not endangered. If the endemic and native bird species of Hawai‘i are to continue into the future, scientists must learn about their preferred habitats and any threats posed by nonnative bird species.

- **State the hypothesis in the form of a question.** *Do larger kīpuka with a greater variety of vegetation and taller vegetation have a greater number and variety of native and nonnative bird species? Another possibility is: Is there a relationship between the variety and height of kīpuka vegetation and the number and variety of native and nonnative bird species?*

Methods

- **How did the large area of forest serve as a control?** *The large area of forest was never isolated as a forested island by volcanic lava. Therefore, it would serve as a setting where, if the volcano had not erupted, the number of native and nonnative bird species would not be dependent on a limited habitat patch size.*
- **Why did the scientists record the type of vegetation and trees found in each kīpuka?** *If the vegetation was different for each or even some kīpuka, any differences in the number of bird species found could be because*

of the vegetation. The scientists would not know whether any differences were related to the type of vegetation or the size of the kīpuka.

Findings

- **Based on the findings, do you think the ‘apapane is likely to be one of the endangered bird species? Why or why not?** *Students may have individual answers to this question. They should, however, suspect that the ‘apapane is not likely to be an endangered species because it can successfully live in a wide variety of kīpuka habitats as well as the large forest.*
- **Read the next-to-the-last sentence in “Findings” and examine table 1. What can you say about the kīpuka and the future of native bird species?** *From this finding, it appears that the smaller kīpuka had fewer nonnative species in them. From table 1, it appears that nonnative species may not often use smaller kīpuka. Therefore, students might conclude that smaller kīpuka appear to provide better habitat for native birds than for nonnative birds. Smaller kīpuka appear to provide a measure of protection for native birds.*
- **Looking over table 1 and figure 14, what can you say about the height of trees in different size kīpuka?** *Students should conclude that the larger the kīpuka size in hectares, the taller the trees.*

Discussion

- **What is one advantage of restoring small forest patches?** *Students will have individual answers, but they should realize that it would cost less to restore small forest patches than larger patches. In addition, smaller patches are less attractive to nonnative species.*

- **What is one disadvantage of restoring only small forest patches?** (Hint: Think about the ‘io or Hawaiian hawk.) *The Hawaiian hawk is endangered, and it was found only in the largest kīpuka. If only small patches of forest are restored, the Hawaiian hawk would be restricted to current areas of large forest.*
- **Why might it be important to begin now to restore patches of native forest at higher elevations?** *Students should realize that trees take years to grow. The tallest trees are often the oldest trees. Because tree height is related to the number of bird species living in a kīpuka, it would make sense to begin restoring small areas of native forest now. This restoration would give the trees a chance to grow. By the time the climate changes enough for mosquitoes to reach the middle elevations, native bird species could move to the higher elevation forest patches.*

BIG Questions

- **Why should humans care about endemic and endangered species? Should the scientists’ recommendation be followed?** *These questions were posed at the beginning of this article. Students should be able to draw on their experience and knowledge, as well as the information presented in this article, to discuss the pros and cons of protecting endemic and endangered species.*

Koa Constrictors

Introduction

- **Explain in your own words why crop trees are needed for products such as surfboards, body boards, furniture, and guitars.** *If the trunk of a tree is bent or twisted, its wood will not be straight enough for boards to be cut from it. If the trunk has a*

lot of side branches, the timber will have a lot of knots. Lumber with knots is not as strong or attractive as lumber without knots.

- **Why did the scientists want to study the three obstacles to koa crop tree growth?** *These obstacles are slowing the growth of koa crop trees. Demand for koa wood, which relies on koa crop trees, is rising. If the scientists could discover ways to overcome these three obstacles, landowners could grow koa crop trees faster now and into the future.*
- **Look at figure 5. Do you see any non-crop koa trees in the photo? How do you know?** *Students should realize that the trees to the left and right of the crop tree are noncrop koa trees because they have crooked trunks. Encourage students to examine this photo so that they understand the differences between crop trees and noncrop trees.*

Methods

- **Explain in your own words why scientists use a control in which no treatment is applied.** *Students will have individual answers to this question. They should, however, recognize that without a control with which to compare the treatments, it would be hard to say what effect the treatments have.*
- **Why did the scientists measure the DBH of the koa crop trees before and after the treatments?** *Students should realize that to identify which treatments, if any, seemed to encourage the growth of koa crop trees, scientists would need measurements both before and after the treatments.*

Findings

- **If you were one of the scientists doing this research, what would you recommend to managers wanting to**

increase the growth rate of koa crop trees? Students should realize that thinning, herbicide use, and the application of phosphorus should be recommended to managers wanting to increase the growth rate of koa crop trees.

- **Is phosphorus important to the growth of koa trees? How do you know?** Students should conclude that phosphorus is important to the growth of koa trees because when phosphorus was added to the soil, the trees more than doubled in diameter. The scientists were so sure about the effects of phosphorus on koa tree growth that they called the growth significant.

Discussion

- **How are koa wood guitars and phosphorus related?** Students should be able to describe how the fertilizer phosphorus, when used in conjunction with herbicide and thinning, encourages the growth of koa crop trees in Hawai'i. Some of these crop trees are used to make koa wood guitars.
- **Why would thinning alone be best done when the trees are young?** When forests are thinned, openings are created that allow more sunlight to reach the remaining trees. Older trees, however, take more than 3 years to respond to the increase in sunlight after thinning. Young trees, because they grow faster, would respond more quickly to an increase in sunlight. If thinning were the only treatment used, therefore, it would be better to do it when the trees were young.

Mangrove Mania

Introduction

- **Mangrove forests provide homes for fish and other wildlife. How could this help support the island's economy?** Locals catch and sell the fish whose habitat is the mangrove forests, thus supporting the island's

economy. Fish and wildlife viewing attracts tourists to the island and helps the economy.

- **What did the scientists want to learn in this study?** The scientists wanted to know how sedimentation and sea-level rise affect mangrove forests.

Methods

- **Why do you think the scientists chose two different islands to study?** Because the scientists could compare their findings and see if there are similarities and differences between the mangrove forest areas.
- **Why do you think scientists measured the islands for 5 to 7 years instead of just 1 or 2 years?** Measuring for 5 to 7 years enabled scientists to measure short-term compared with longer term trends in sedimentation and sea-level changes.

Findings

- **Why do you think harvesting of overstory trees may have affected the soil elevation?** It is possible that, after trees were killed, their roots were no longer able to help stabilize the soil. It is also possible that the loss of the tree canopies, which deflect and slow down the rain, allowed hard rains to fall directly on the soil and created more soil erosion.
- **Why do you think fringe areas generally lost soil elevation over the time period studied?** The fringe areas are subject to more wave action and, therefore, may lose more sediment and soil.

Discussion

- **Why is it important for tropical land managers to learn how best to manage the land around mangrove forests?** Mangrove forests help protect the island from

waves and sea-level rise. The mangrove forests are important to the ecology and economy of the island.

- **Why is it important for people living on the islands to be concerned about rising sea levels?** *Rising sea levels can have an enormous impact on the island. For example, fringe areas could be completely under water. The water would impact the mangrove forests that provide many benefits to the islanders. (Reread the “Introduction” section that lists the ways mangrove forests are beneficial.)*

Beam Me Down, Scotty!

Introduction

- **Why did the scientists study Hawai‘i?** *Because the scientists were testing a method of carbon estimation, it would be most helpful to test the method with different types of land use and ecosystems. Hawai‘i was a perfect place to study because it is a large area, it has a clear boundary, and it has a variety of land cover and ecosystems.*
- **What was the problem the scientists were trying to solve?** *The scientists needed to be able to estimate the amount of carbon being stored across large land areas and in different types of land cover. This method for estimating needed to be cost effective and fairly accurate. The problem was that scientists had not yet tested effective methods for estimating carbon storage across large and diverse areas.*

Methods

- **How was the old method of estimating carbon in person combined with new technologies?** *The scientists sampled a wide variety of ecosystems and land covers in person and estimated the amount of carbon contained in those areas. Then, they used the advantage*

of LiDAR to calculate the height of trees to relate the amount of carbon in an area. The scientists compared the more accurate in-person method with LiDAR’s ability to sample large areas.

- **What if the scientists wanted to map the carbon contained in the State of West Virginia? Should they use the same estimate of carbon related to the vertical center as they did in Hawai‘i? Why or why not?** *Students will have individual answers to this question. They should realize, however, that because some of the ecosystems in West Virginia might be different than those in Hawai‘i, the scientists should follow the same four steps to make sure that their estimates are accurate. They should not simply take the estimates made in Hawai‘i and apply them to West Virginia without testing them first.*

Findings

- **Why would areas with old soils contain more carbon than areas with young soils?** *Students will have individual answers to this question. They may realize, however, that young Hawaiian soils are created from lava flow, which only over time become more able to support vegetation and trees as organic matter is accumulated. Areas with recent lava flow have little to no soil and do not support vegetation.*
- **Why do you think the amount of carbon was related to the amount of rainfall in different areas of Hawai‘i?** *Students will have individual answers to this question. They should realize, however, that rainfall is necessary for plant growth. Higher rainfall leads to more vegetation. More vegetation means more carbon storage.*

Discussion

- **Would you say that the scientists' test of their new method to estimate the amount of carbon in Hawai'i was successful? Why or why not?** *Students should conclude that the test of this new method was successful. They should come to this conclusion because scientists were able to create an accurate carbon map of the entire island of Hawai'i using their method that combines the in-person calculations with new technology.*
- **Do you think that this method could be used for other large areas of forest and other land cover? Why?** *Students should realize that this method could be used for any defined area of land to estimate carbon storage as long as land cover maps or Landsat photographs, DBH-carbon equations, and LiDAR measurements were available or could be obtained.*

Don't Litter the Stream!

Introduction

- **State what the scientists wanted to know in the form of a question.** *Are organisms living in some Hawaiian streams eating albizia leaf litter instead of algae? Or, has albizia leaf litter replaced algae as the base of the food web in some Hawaiian streams?*
- **Review "Thinking About Science."** **How do you think the scientists might have answered their question?** *Students will have individual answers, but they should realize that the scientists would use technology to help them understand how much nitrogen was in the organisms that might be eating albizia leaf litter. Students should also realize that the scientists would have to compare*

this amount with the amount of nitrogen in organisms in streams with no albizia growing nearby.

Methods

- **Why did the scientists have to find streams that were alike in every way except for the albizia trees growing nearby?** *If there were other differences between the streams, then the scientists would not know if any observed differences in the diets of the aquatic consumers were because of the albizia or something else.*
- **Finding higher-than-normal levels of nitrogen in the tissues of consumers might lead the scientists to what conclusion about albizia leaves as a food source?** *That albizia, whose leaves contain a lot of nitrogen, was being used as a food source for aquatic consumers.*
- **Reading the captions of figures 6-10, what might you include about the aquatic organisms in this stream?** *Students may have other observations, but one that stands out is that only one of the aquatic organisms is native to Hawai'i.*

Findings

- **Look at the way the numbers occupy the cells in tables 1 and 2. Both show a pattern from left to right. Why do the cells increase from left to right?** *Students should realize that these tables are showing a food web that includes more consumers being consumed as one goes up the food chain. The consumers on the right are at a higher level. Educators may want to introduce the idea of trophic levels to the class at this time.*

- **Compare the first row in tables 1 and 2. What does this row reveal about albizia as a food source?** *This row indicates that albizia is a major food source for amphipods and caddisflies where albizia is growing.*

Discussion

- **If the stream food webs change across Hawai'i because of albizia, do you think the food webs that exist on the land beside streams could change as well? Why or why not?** *Because some land-based animals eat aquatic animals, the increase in nitrogen may be passed to animal species living near the streams.*
- **An increase in nitrogen in Hawaiian streams may cause more algae to grow. If more algae grow, how might the stream be further changed by albizia?** *Students will have individual answers to this question. Students may realize that if albizia trees continue to be the preferred food, too much algae could grow in the stream because of the increased nitrogen and fewer consumers would be eating it. Too much algae in the stream could become a problem.*

Left High and Dry?

Introduction

- **Why do you think it is important to save native ecosystems?** *Students will have individual answers to this question. They should, however, back up their reasons with logic. Some possible answers are to preserve the habitat of native birds, mammals, and insects; to save the few remaining trees or plants of a particularly endangered species; to stop the spread of invasive species; and to preserve the cultural values of native ecosystems.*
- **What is one way to restore a native forest?** *Students will have individual answers to this question. They should, however, back up their reasons with logic. Some possible answers are to plant seeds of native plant and tree species; to plant small native trees and other native plants; to remove the invasive plants; and to exclude any animal species that are destroying the native plants and trees.*
- **What question did the scientists want to answer? What things were done that created success in the restoration of the dry tropical forest? What did the scientists want to do after they answered their question?** *They wanted to develop recommendations for others interested in restoring dry tropical forests, anywhere they are found.*

Methods

- **Why do you think the scientists wanted to keep track of each plant species and the date of planting?** *Students will have individual responses, however, they should back up their answers with logic. Students should realize that it would be impossible to calculate how many plants and trees of each species had died without the tags, and that the age of the plant was needed to determine how long the plants and trees had survived.*
- **From this method, could the scientists determine whether it was necessary to kill the grass with a chemical after they had cut it? Why or why not?** *Students should realize that the scientists could not say whether they needed to kill the grass with a chemical. They could not say this because they killed all of the grass. If the scientists had left some areas of grass alive after cutting it, they could have compared the areas of cut grass with areas of grass that had been cut and had the chemical applied.*

Findings

- **How is the effect of the drought from 1999 to 2003 reflected in figure 10?** *The numbers in parentheses indicate the percentage of surviving plants. With the exception of 1999, the last 2 years of the drought had the lowest percentage of surviving plants. How is the year of high rainfall reflected in figure 10?* *The percentage of surviving plants increased from 27 percent in 2003 to 52 percent in 2005 following the high rainfall in 2004.*
- **Examine figures 10 and 11. Would you say the planting effort was a success? Why or why not?** *The overall survival rate of 30 percent was not high, indicating that the planting effort may not have been successful. The percentage increase in endangered plant and tree populations, however, ranged from 3 percent to 9,733 percent. This could be considered a big success, especially for the koki'o, which is now considered extinct in the wild.*

Discussion

- **State in your own words what the most important finding is from this study.** *The steps people should take in the future if they want to restore native dry tropical forests. How did the scientists determine this finding?* *They learned from their mistakes.*
- **How can you apply this finding to your own life?** *Students will have individual answers to this question, but they should understand that success should sometimes be measured not by the outcome of an action, but by our future action in response to it. If we learn from our mistakes, we can consider our effort a success.*

Which National Science Education Standards Can These Articles Address?

	Treasure Islands	Koa Constrictors	Mangrove Mania	Beam Me Down, Scotty!	Don't Litter the Stream!	Left High and Dry?
Science As Inquiry						
Abilities Necessary To Do Scientific Inquiry						
Understandings About Scientific Inquiry						
Life Science						
Structure and Function in Living Systems						
Regulation & Behavior						
Populations & Ecosystems						
Diversity & Adaptations of Organisms						
Reproduction & Heredity						
Earth Science						
Structure of Earth System						
Natural Hazards						
Populations, Resources, & Environments						
Science & Technology						
Understandings About Science & Technology						
Science in Personal & Social Perspectives						
Risks & Benefits						
Science & Technology in Society						
History & Nature of Science						
Science As a Human Endeavor						
Nature of Science						

Which National Curriculum Standards for Social Studies Can Be Addressed by These Articles?

	Treasure Islands	Koa Constrictors	Mangrove Mania	Beam Me Down, Scotty!	Don't Litter the Stream!	Left High and Dry?
Culture						
Time, Continuity, & Change						
People, Places, & Environments						
Individual Development & Identity						
Power, Authority, & Governance						
Production, Distribution, & Consumption						
Science, Technology, & Society						
Global Connections						
Civic Ideals and Practices						



What Is the Pacific Southwest Research Station?

The Pacific Southwest (PSW) Research Station represents Forest Service Research and Development in the States of California and Hawai'i and the U.S.-affiliated Pacific islands. The region has the lowest, driest desert in the country, the highest elevations within the 48 contiguous States, and the wettest tropical forests. It is the home of an abundant diversity of native plants and animals and nearly 50 percent of the Nation's threatened and endangered species. PSW scientists conduct a broad array of natural resources research to achieve its mission to "develop and communicate science needed to sustain forest ecosystems and their benefits to society."

<http://www.fs.fed.us/psw/>

What Is the Forest Service?



The Forest Service is a part of the U.S. Department of Agriculture (USDA). It is made up of thousands of people who care for the Nation's forest land. The Forest Service manages more than 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 are public lands, meaning that they are owned by the public and managed for the public's use and benefit. Both national forests and national parks provide clean water, homes for the 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 the 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.

<http://www.fs.fed.us>

What Is the Cradle of Forestry in America Interpretive Association?



The Cradle of Forestry in America Interpretive Association is a 501(c)3 nonprofit organization based out of Brevard, NC. The Interpretive Association strives to help people better understand ecology through recreation and education opportunities. Their projects include:

- Campground and recreation area management.
- Educational programs and services, including the *Natural Inquirer* and the *Investi-gator*.
- Sales of forest-related gifts and educational materials.
- Workshops, newsletters, and publications.
- Partnership with the Forest Service to provide programming at the Cradle of Forestry in America Historic Site.

<http://www.cfaia.org>

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United States
Department
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Forest Service

FS 994
Spring 2012

Editorial Review Board

David Pavel's combined 7th and 8th grade science class
Laupahoehoe High and Elementary School, Laupahoehoe, HI



Web Site Resources

Natural Inquirer:
<http://www.naturalinquirer.org>

Investi-gator:
<http://www.scienceinvestigator.org>

Forest Service Conservation Education:
<http://www.fs.usda.gov/conservationeducation/>

Forest Service Pacific Southwest Research Station:
<http://www.fs.fed.us/psw/>

Forest Service Institute of Pacific Islands Forestry:
<http://www.fs.fed.us/psw/locations/hilo/>

Hawai'i Experimental Tropical Forest:
<http://www.hetf.us/>

Hawai'i Volcanoes National Park:
<http://www.nps.gov/havo/>

U.S. Geological Survey (USGS) Hawai'i volcanoes page:
<http://hvo.wr.usgs.gov/>