

Natural

INQUIRER

Number 19

THE

CITIZEN SCIENCE

EDITION

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Natural Inquirer

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Cradle of Forestry in America

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Production Staff

Babs McDonald, Forest Service

Jessica Nickelsen, Cradle of Forestry in America Interpretive Association

Brian Cooke, Cradle of Forestry in America Interpretive Association

Samantha Dean, Cradle of Forestry in America Interpretive Association

Michelle Andrews, University of Georgia

Shonté Jenkins, U.S. Geological Survey

Stephanie Pfeiffer, SMP Illustration

Carey Burda, Cartographer

USDA and Forest Service Scientists Highlighted in the Journal

Ann Bartuska, Research, Education and Economics, U.S. Department of Agriculture

Duncan McKinley, Washington Office, Research and Development, Policy Analysis Staff

Yvette Ortega, Rocky Mountain Research Station

U.S. Geological Survey Scientists Highlighted in the Journal

Pamela Schofield, Southeast Region

David Wald, Southwest Region

Bruce Worden, Southwest Region

Collaborating Scientists

Lad Akins, Reef Environmental Education Foundation

Aubree Benson, University of Montana

Russell Briggs, State University of New York

J. Marcus Drymon, University of South Alabama

Erick Greene, University of Montana

Charles Martin, Louisiana State University

Steven Scyphers, Northeastern University

Forest Service

Thomas L. Tidwell, Chief

Carlos Rodriguez-Franco, Deputy Chief, Research and Development

Victoria Christiansen, Deputy Chief, State and Private Forestry

Tony Ferguson, Director, Northern Research Station

Michiko Martin, Staff Director, Conservation Education

Tracy Hancock, Staff Director, Knowledge Management & Communication

Greg Arthaud, Research Social Scientist, Landscape Restoration and Ecosystem Services Research

Kimberly Winter, National Program Leader, NatureWatch

Duncan McKinley, Policy Analyst, Policy Analysis

Michelle Tamez, Natural Resource Specialist, Ecosystem Management Coordination

Natural Inquirer Governing Board

Tony Ferguson

Paulette Ford

Christian Giardina

Tracy Hancock

William Lange

Ariel Lugo

Michiko Martin

Chelcy Miniati

Kimberly Winter

U.S. Geological Survey

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Carl Shapiro, Director, Science and Decisions Center

Ellie Brown, Deputy Director, Science and Decisions Center

Sophia B. Liu, Participatory Science and Innovation Lead, Science and Decisions Center

Cradle of Forestry in America Interpretive Association

Hope Ascher, Chairperson

Carlton Murrey, Executive Director

Adam DeWitte, Education Director

With thanks to

Liz Burke, Forest Service, Conservation Educator

Victoria Houser, Forest Service, Recreation Staff Officer

Aleksandra Pitt, Colorado State University, Graduate Student

Courtney Schultz, Colorado State University, Assistant Professor

Margalit Fox, The New York Times, Senior Writer

Dolores Morrison, The New York Times, Picture Editor

Project Learning Tree, <http://www.plt.org/>

Forest Service Youth Forest Monitoring Program, <https://youtube.com/XqFRpW4xtyQ>

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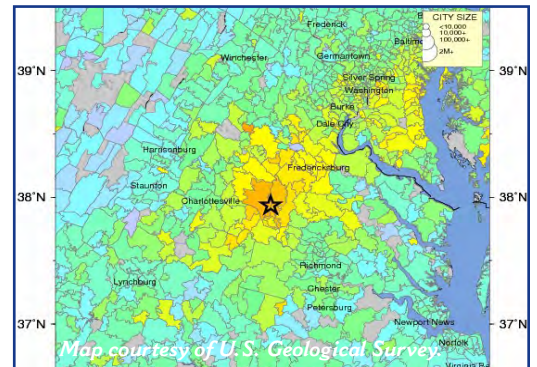
Join us in being green! The following Educator Resources are now available exclusively on the *Natural Inquirer* website: <http://www.naturalinquirer.org>. These resources can be found with the "Citizen Science" journal and on the "For Educators" pages.

- Note to Educators
- Lesson Plan
- Reflection Section Answer Guide
- National Education Standards (specific to each article), including:
 - National Science Education Standards
 - National Curriculum Standards for Social Studies
 - Common Core State Standards
 - Next Generation Science Standards

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58



Editorial Review Boards



Photo courtesy of Liz Burke.



Photo courtesy of Liz Burke.



Photo courtesy of Liz Burke.

Natural Inquirer editorial review boards hard at work.

Editorial Review Boards' Comments

Anderson Middle School, Montana: Ms. Hagengruber's 7th Grade Science Classes

I think it's really good to have a glossary, and it helps to have the web resources.

I think that the maps should be a bit bigger and it would be great.

Some of the graphs could be confusing because the numbers and writing are pretty small.

My suggestion is to add more warm inviting colors such as reds, oranges, and yellows. More colors might attract more students and teachers. The blues and greens are too neutral for a student magazine.

I really like the Natural Inquirer, it is very informational.

I love how it is set up, the font is perfect and the pictures are great; the graphs are easy to read.

You should make the colors a little more bold.

The font is readable but a bit too large in my opinion.

It was really drawn out and took a long time to get to the point.

They use the word "science" and "scientists" too often, they need more variety in their vocabulary.

I loved the pictures! The captions were large, and I sometimes got them confused with the text.

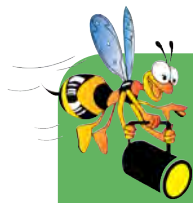
Tell what year or time of year the photos were taken.



Photo courtesy of Liz Burke.



Photo courtesy of Liz Burke.



Spotlight on the Youth Forest Monitoring Program

The Youth Forest Monitoring Program (YFMP) is a summer internship program for students in grades 9–12. Participants learn about forest ecology, explore their local forest lands, engage in forest health monitoring, and network with professionals. YFMP provides training, including spending 6 weeks in the field learning how to monitor forest health, receiving instruction in the classroom, and working in the laboratory. Students complete the program by presenting their data and conclusions to parents, the public, and Forest Service personnel.



Photo courtesy of Aleksandra Pitt.



Photo courtesy of Forest Service, Northern Region.



Photo courtesy of Forest Service, Northern Region.

- “You can never fully experience nature until you dive into it.” – Keaton Habeck
- “Science is rad, and science is what we use to protect the places that we love.” – Kris Bosch
- “Being outside and experiencing amazing places in nature has been a fantastic way to spend my summer!” – Meghan Robinson

YFMP is supported by Helena National Forest, Montana Discovery Foundation, Helena College of Technology, and local counties. For more information, watch <https://www.youtube.com/watch?v=XqFRpW4xtyQ>.

About *Natural Inquirer*

Scientists report their research in journals, which are special booklets that enable scientists to share information with one another and with others. This journal, *Natural Inquirer*, was created so that scientists can share their research with you and other middle school students. This journal presents the research of scientists with the U.S. Geological Survey, the Forest Service, and other cooperating organizations.

The U.S. Geological Survey is an agency of the U.S. Department of Interior. The Forest Service is an agency of the U.S. Department of Agriculture. If you want to know more about the U.S. Geological Survey or the Forest Service, you can read about them on the inside back cover of this journal. Information is also available at <http://www.usgs.gov> and <http://www.fs.fed.us>.

All of the research in *Natural Inquirer*, concerns 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. Don’t forget to look at the glossary and the special sections highlighted in each article. 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.

Be sure to try the Citizen Science Crossword and eyeChallenge on pages 83 and 84!

Who Are Scientists?



Photo courtesy of Yvette Ortega.



Photo courtesy of David Wald.



Photo courtesy of Tim Baldwin.



Photo courtesy of Russell Briggs.



Photo courtesy of Pam Schofield.

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

- ❖ **Be curious**—Are you interested in learning?
- ❖ **Be enthusiastic**—Are you excited about a particular topic?
- ❖ **Be careful**—Are you accurate in everything you do?
- ❖ **Be open-minded**—Are you willing to listen to new ideas?
- ❖ **Question everything**—Do you think about what you read and observe?

To learn more about your favorite scientists and their work, you can view and order scientist cards and print your own posters online at <http://www.naturalinquirer.org>.

to the *Natural Inquirer* Citizen Science Edition!

Have you ever observed the arrival of a particular bird or butterfly species in spring? Have you noticed when or where a particular flower blooms? Did you know that your observations could be a part of a real scientific research project?

Projects that include people like you who collect and submit observations and information have a number of names. Most commonly, these projects are called citizen science. Other names for citizen science include crowd science, crowd-sourced science, citizen-based science, civic science, volunteer **monitoring**, and networked science. All of these names identify a scientific project that includes citizens—people like you—as a part of the information collection process.

Some citizen science projects involve a website. At the project's website, you learn how to properly make, record, and report your observations. Usually, the website also includes online forms so that you can submit your information electronically.

For some citizen science projects, you can track the collection of similar information from citizens and students nationwide and even worldwide. Throughout this journal, you will find out about many citizen science projects. You can learn more about each one on the website listed with each article.

In this *Natural Inquirer*, you will learn about the many benefits of citizen science, to both the scientist and the citizen scientist. You will learn about the kind of science that can be supported by observations you and your classmates make. You will learn, for example, how the observations of **spearfishers** and volunteers compare with the observations of **marine** scientists. You will learn how your own bird observations and observations of **invasive species** relate to similar science

being done by scientists. Have you ever felt an earthquake **tremor**? You will learn how people who feel earthquake tremors are contributing to a better understanding of earthquakes.

After reading this *Natural Inquirer*, you can become a citizen scientist too!



Photo courtesy of Aleksandra Pitt.



Photo courtesy of Aleksandra Pitt.

Glossary words are **bold** and are defined on page 7.

Citizen Science For Life

Can you imagine observing, recording, and reporting the weather every single day? That is what Richard G. Hendrickson did—for 85 years! Beginning when he was 17 years old, Mr. Hendrickson observed and recorded the weather at 8 a.m. and 8 p.m. every day. He volunteered for the Cooperative Observer Program, which became the National Weather Service. The National Weather Service is a part of the National Oceanic and Atmospheric Administration (NOAA).



Photo courtesy of Dolores Morrison.



Photo courtesy of Dolores Morrison.

As time passed, other volunteer weather observers started to report the weather using computers. Mr. Hendrickson never did. Instead, he phoned in his weather reports twice a day. When Mr. Hendrickson died at the age of 103, he was the Nation's longest serving volunteer weather watcher.

In 2014, NOAA established the Richard G. Hendrickson Award. This award is presented to volunteers with 80 years of service. Mr. Hendrickson was the award's first recipient. Mr. Hendrickson's commitment to observing and

reporting the weather helped scientists and citizens across the country by providing timely, accurate weather data and helped chart the way for studying weather. You can be like Mr. Hendrickson! After reading this journal, select a topic and become a citizen scientist too!

This information is adapted from a *New York Times* article. To learn more and read the full article, visit <http://www.nytimes.com/2016/01/18/nyregion/richard-g-hendrickson-who-recorded-the-weather-for-85-years-dies-at-103.html>.

Check out the National Weather Service video about Mr. Hendrickson at <https://youtube/F2-e6WsCI2l>.

Is Citizen Science New?

Before science emerged as a profession, citizen scientists conducted most of the scientific research. Over hundreds of years, **amateur** scientists and volunteers contributed to an understanding of climate, evolution, geology, electricity, astronomy, and other topics. Farmers, weather watchers, and **naturalists** documented the daily weather, the timing of harvests and insect outbreaks, and wildlife sightings and behavior. Three North American citizen scientists you may be familiar with are Benjamin Franklin, Benjamin Banneker, and Thomas Jefferson. Benjamin Banneker, who lived in the late 1700s, was an amateur astronomer and naturalist.

So, if you practice citizen science, you are following in the footsteps of people interested in carefully observing the natural world.



In 1980, the U.S. Postal Service honored Benjamin Banneker with a U.S. stamp. Photo by Babs McDonald and enhanced by Stephanie Pfeiffer.

Glossary

amateur (a mə tər): A person who does something (such as a sport or hobby) for pleasure and not as a job.

invasive species (in vā siv spē shēz): Any plants, animals, or organisms that are not native to the ecosystem they are in, and are likely to cause harm to the environment, the economy, or human health.

marine (mə rēn): Of or relating to the sea or the plants and animals that live in the sea.

monitor (mä nə tər): To watch, observe, listen to, or check (something) for a special purpose over a period of time.

naturalist (nat u ral ist): A person who studies plants and animals as they live in nature.

spearfisher (spēr fi shər): A person who, while swimming below the water's surface, fishes using a spear.

tremor (trə mər): Something discharged or sent out.

Accented syllables are in **bold**. Marks and definitions are from <http://www.merriam-webster.com>. Definitions are limited to the word's meaning in the article.

Device-ive Science

***How Electronic
Devices
Encourage
Citizen
Involvement With
Environmental
Research***



Photo courtesy of Ian Callow.

Meet the Scientists

► **Dr. Duncan McKinley**, Policy Analyst (ə nə ləst): My favorite science experience was finding a new species of cricket. I found the cricket when I was a high school student volunteering with the Student **Conservation** Association and the Forest Service.



Photo courtesy of Duncan McKinley.



Photo courtesy of Russell Briggs.

◄ **Dr. Russell Briggs**, Soil Scientist: My favorite science experience is teaching students and professionals how to describe the range of soil characteristics that can be observed in the field.

► **Dr. Ann Bartuska**, Ecosystem Ecologist: My favorite science experience was the quiet of the maple forest in West Virginia as I collected leaf litter samples in **decomposition** bags to return to the laboratory for weighing. A fun science experience was standing in a West Virginia wetland in early spring with a thermometer to test whether the internal temperature of skunk cabbage before the buds expanded really DID hit 85° Fahrenheit...as reported in the journal *Scientific American*. It only hit 82°F!



Photo courtesy of Ann Bartuska.

Glossary words are **bold** and are defined on page 17.

What Kinds of Scientists Did This Research?

ecosystem ecologist: This scientist studies the interactions of organisms with each other and with nonliving parts of their environment.

policy analyst: Policy analysts review, evaluate, and **monitor** policies and legislation. They also write reports that **synthesize** various types of information.

soil scientist: This scientist studies soils as one of Earth's natural resources.



Figure 1. Mobile and electronic devices are an important part of most people's lives. Photo courtesy of Ian Callow.

Thinking About Science

Like everything else, science changes over the years. Many scientific changes are happening because technology is rapidly advancing. Twenty years ago, few people imagined that hand-held mobile devices would be at the center of our lives (**figure 1**). Few people thought that phone calling, emailing, texting, playing video games, and watching videos would be possible by reaching into their pocket. As computer chips got smaller, these technological advances became possible.



At the same time, users access large computers (known as the “cloud”) through the Internet. Exchanging information among these large computers enables scientists to **analyze** larger and larger amounts of information. Scientists can combine large **datasets** to answer questions that no one had imagined just a few years ago. People with mobile devices can now also access a range of information because of these networked computers. Computers have made science more accessible to almost everyone.

Thinking About Environment

Scientific topics related to the natural environment may change because of what people have learned from past scientific studies. In forest science, for example, scientific priorities have changed over the years. In the 1940s and 1950s, scientists studied ways to increase the amount of wood that could be cut from national forests (**figure 2**). They studied how to put wood to the best use.

In the 1960s and 1970s, environmental protection became an important scientific topic. Since 1993, much forest science has focused on ecosystem services and how natural resources can be managed **sustainably**. Ecosystem services are environmental health benefits and human benefits provided by a community of plant and animal species. Examples of ecosystem benefits include clean air, clean water, outdoor recreation, beautiful scenery, and wildlife habitat (**figure 3**).



Society may also influence natural resource science topics. For example, people might be asked to reduce their water use because of a period of time when little to no rain has fallen. These people might become more concerned about having enough clean water. This concern will influence scientists, who will then study ways to better conserve water supplies. You can see that society and science are closely related. Both past scientific findings and social needs influence the topics that scientists study.



Figure 2. Manti-La Sal National Forest, Utah. National forests are large areas of forest that the Forest Service manages on behalf of all Americans. For more information about national forests, visit <http://www.fs.fed.us/managing-land/national-forests-grasslands>. Photo courtesy of Babs McDonald.

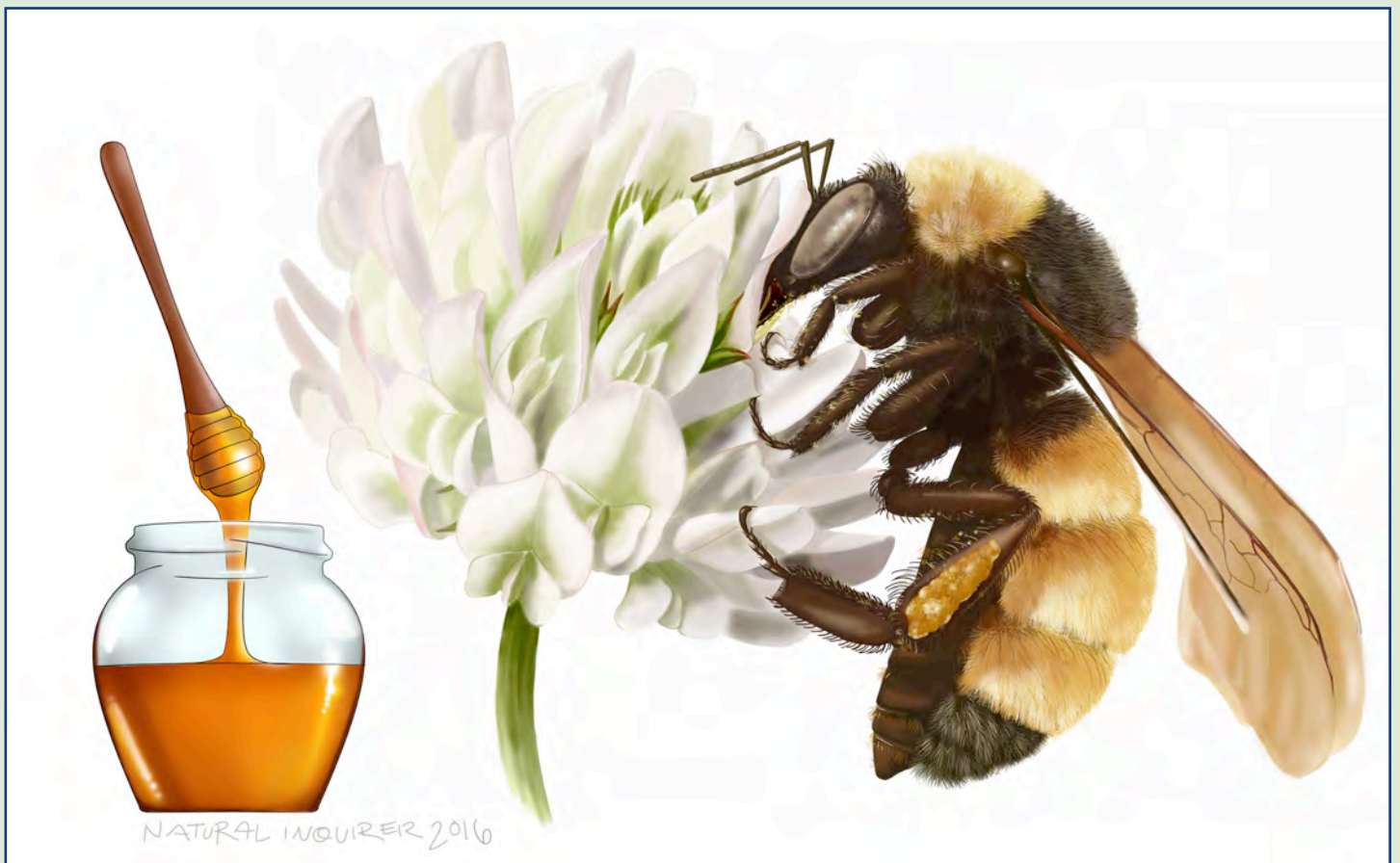


Figure 3. Ecosystem services have become an important topic for natural resource scientists. Ecosystem services are the benefits that nature provides through natural processes. People benefit from ecosystem services, such as flower pollination. Illustration by Stephanie Pfeiffer.

Introduction

Before the introduction of personal computers, tablets, cell phones, and other mobile devices, scientific findings were more difficult to share widely. People read about some scientific advances in magazines and newspapers or learned about them on TV or the radio (**figure 4**). Scientists presented findings in person to other scientists or to people interested in their topic. Scientists wrote about their findings and published them in hard-copy science journals. These journals are similar to *Natural Inquirer*, but are written for other scientists (**figure 5**). Ordinary citizens, however, had a more difficult time gaining

access to a wide range of recent scientific results. Now that most people have access to computers and mobile devices, getting recent scientific information is easier (**figure 6**). These devices also make it easier for citizens to communicate with scientists.

The scientists in this study wanted to know how new technology has affected the relationship among scientists, science, and citizens. The scientists wanted to understand how the Forest Service can more effectively involve citizens with their scientific projects. (Learn more about the Forest Service by reading the inside back cover of this journal.)

Who Is a Citizen?

Often the word “citizen” means a legal member of a particular country, such as a U.S. citizen. Merriam-Webster’s dictionary also defines “citizen” as a person who lives in a particular place. In this article, the word “citizen” refers to any person who lives in a community.

Reflection Section

- What questions did the scientists want to answer?
- Name one way that better computer access has changed the relationship among scientists, science, and citizens.



Figure 4. In the past, when citizens were interested in recent scientific findings, they usually read about them in newspapers and magazines. People also learned about scientific findings on TV and the radio. Photo courtesy of Babs McDonald.

ISSUES IN ECOLOGY

Published by the Ecological Society of America

Investing in Citizen Science Can Improve Natural Resource Management and Environmental Protection

Duncan C. McKinley, Abraham J. Miller-Rushing, Heidi L. Ballard, Rick Bonney, Hutch Brown, Daniel M. Evans, Rebecca A. French, Julia K. Parrish, Tina B. Phillips, Sean F. Ryan, Lea A. Shanley, Jennifer L. Shirk, Kristine E. Stepenuck, Jake F. Weltzin, Andrea Wiggins, Owen D. Boyle, Russell D. Briggs, Stuart F. Chapin III, David A. Hewitt, Peter W. Preuss, and Michael A. Soukup



Figure 5. Scientific papers published in science journals are usually more challenging for nonscientists to read. Photo courtesy of Babs McDonald.

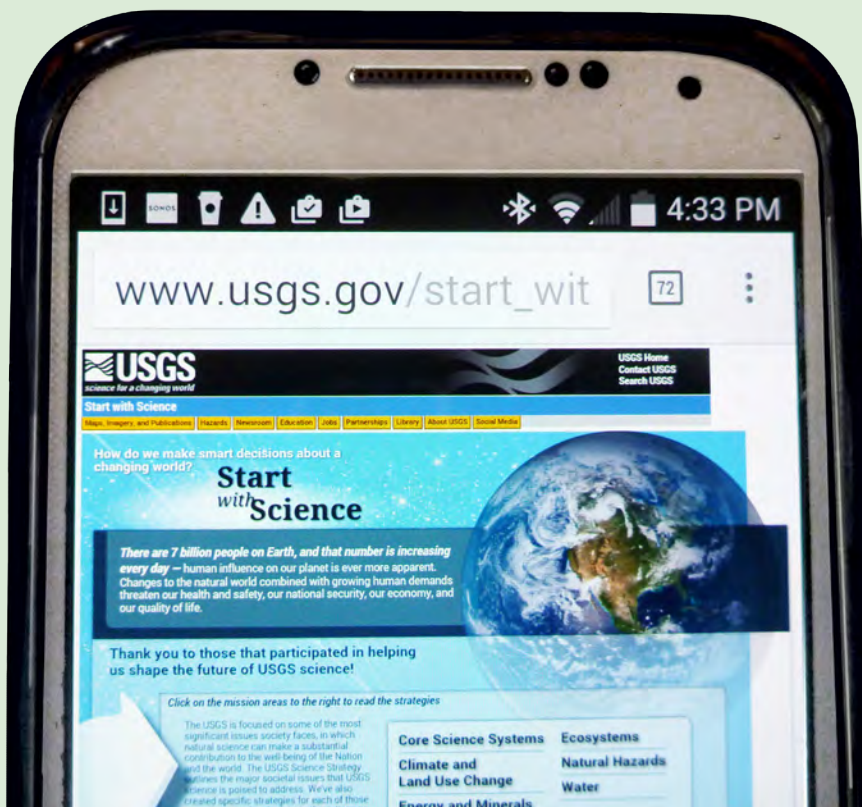


Figure 6. Getting access to recent scientific findings is easier today because of personal computers and mobile devices. Photo courtesy of Babs McDonald.

Methods

The scientists searched online and through printed science journals for information related to their questions. They read more than 100 papers discussing citizen involvement with science projects (**figure 7**). The scientists conducted interviews and spoke with people practicing citizen science. Citizen science is the practice of including volunteers in the process of scientific study (**figure 8**). The scientists also relied on their own experience to better understand the involvement of citizens in the scientific process.

The scientists read about the ways that scientists share their results and how citizens

learn about scientific results. Using all of the information they collected, the scientists explored different ways that citizens have been involved in scientific projects.

The scientists examined how new technology has made it easier for citizens to participate in science projects. For example, citizens can use their cell phones and tablets to record and submit data. Citizens can also use their tablets and cell phones to identify plant and animal species. Finally, the scientists considered whether using citizens to help with science projects is a **viable** way for Forest Service scientists to do their research.

Wildlife Society Bulletin

Published by: [The Wildlife Society](#)

Wildlife Society Bulletin 34(5):1425-1429. 2006

doi: [http://dx.doi.org/10.2193/0091-7648\(2006\)34\[1425:TROCSA\]2.0.CO;2](http://dx.doi.org/10.2193/0091-7648(2006)34[1425:TROCSA]2.0.CO;2)

The Reliability of Citizen Science: A Case Study of Oregon White Oak Stand Surveys

AARON W. E. GALLOWAY^{1,2a}, MARGARET T. TUDOR^b, and W. MATTHEW VANDER HAEGEN^c

Abstract

We trained students (grades 3–10) through classroom presentations to survey an Oregon white oak (*Quercus garryana*) stand in Washington, USA, and compared their data to those obtained from professionals. In May and July 2002, 607 students and 8 professionals surveyed 59 and 22 50-m transects, respectively. We enumerated oaks and ponderosa pines (*Pinus ponderosa*), measured diameter at breast height, and rated the crown shape of oaks. Oak diameter at breast height measurements and tree counts were consistent between students and professionals ($\alpha = 0.05$), but subjective crown assessments and live or dead status differed. Students tended to overreport relatively rare pines and larger oaks relative to professionals. This project provided resource managers with data describing oak diameter at breast height and distribution while educating students about the ecology of local wildlife habitat.

West, Associate Editor

Published: December 2006

Keywords: [citizen science](#), [data reliability](#), [Oregon white oak](#), [Quercus garryana](#), [Washington](#)

Figure 7. The scientists read more than 100 papers like this one related to the topic of citizen science. This study compared data, or information, collected by students with data collected by scientists. Image courtesy of Babs McDonald.



Figure 8. Citizen science projects usually engage citizens with data collection for scientific projects. Photo courtesy of the Forest Service, Northern Region.

Reflection Section



- ❦ Pretend you are one of the scientists in this study. What would you ask other scientists if you were interested in whether citizen science can be a successful way to conduct research?
- ❦ Name two ways that new technology makes it easier for citizens to participate in citizen science projects.



Lend a Hand
Care for the Land

Citizen Science Connections

Volcanic ash consists of tiny, sharp particles of rock and natural glass that are blasted into the air during a volcanic eruption. Volcanic ash can threaten the health of people, livestock, and wildlife. It also poses a hazard to flying jets, can damage electronics and machinery, and can interrupt electric power and telecommunications. Alaska has many active volcanoes, averaging two eruptions per year.

Is Ash Falling? is a citizen science project that helps scientists better understand volcanic activity. Scientists ask citizens to collect data about ash fall in Alaska.

Is Ash Falling? lets citizen scientists:

- Report observations of volcanic ash online;
- Collect ash samples and send them to the Alaska Volcano Observatory;
- Contribute to public health and safety;
- Contribute to science.

For more information, visit <https://www.avo.alaska.edu/ashfall/ashreport.php>.



Photo courtesy of Game McGimsey, the Alaska Volcano Observatory and the U.S. Geological Survey.

Findings

The scientists found that professional scientists still conduct most of the scientific research. However, citizens can help professional scientists by collecting data, sharing results, and understanding the findings.

The scientists discovered that working with citizens enables professional scientists to expand the **spatial** or **temporal** scope of their research. Citizens may rapidly collect information, and since they are volunteers, costs may be lower. Another benefit of involving citizens in science projects is that citizens sometimes have a lot of experience with and knowledge about the topic. These citizens might know a lot about the local environment. This experience and knowledge helps scientists to understand their results (figure 9).

The scientists found a few barriers to involving citizens in some science projects.

Some kinds of data collection, for example, require too much specialized training. For projects that can include citizens, however, citizens benefit by learning about the research topic. Citizen scientists also benefit by learning the scientific method and improving their observation skills (figure 10).



Figure 9. Citizens can help scientists understand findings because of their knowledge or experience with a topic. These local citizens are measuring the diameter of a live oak tree in coastal Georgia. Photo courtesy of James Holland.

Reflection Section

- Brainstorm a number of natural events that your class could observe, record, and submit to scientists. Discuss why having this information might be helpful to scientists.
- Think of a person who has a lot of knowledge and experience with a particular topic. How could that person's knowledge and experience help a scientist?



	Regular Science	Citizen Science
What is the research for?	Scientific understanding: potential application to management.	Scientific understanding: public involvement and improved science understanding and potential application to management.
Who is the research for?	The public, institutions, and professionals.	The public, institutions, professionals, individual citizens, and citizen groups.
Whose knowledge matters?	Scientists.	Scientists and citizens.
The scientific method used is chosen for...	Proper scientific methods.	Proper scientific methods: public involvement and learning.
The main research purpose is...	Hypothesis testing; discovery.	Monitoring and biological understanding.

Figure 10. The scientists compared regular science with citizen science.

Discussion

Access to science is increasing with new technology. Many citizen science projects, however, do not require new technology to be involved. This technology is also supporting public interest in and concern about the natural environment. More often, these interests and concerns influence which topics environmental scientists study.

New technology also makes it easier for citizens to contribute to certain kinds of environmental science projects. Citizen involvement in science projects can increase

the amount of information available to scientists. Citizen involvement can also improve scientists' understanding of their topic.

Citizen scientist projects enable citizens to learn more about the environmental topics that interest them. These projects enable citizens to contribute to both science and the environment. Finally, citizen science projects may increase the efficiency of collecting information by expanding the area being studied and the number of observations that can be made.



Reflection Section

- ✿ Think about your own access to technological devices. To which environmental science topic would you like to contribute? How do you think you could contribute?
- ✿ How would you benefit from being involved in an environmental citizen science project?

Glossary

analyze (ə nə līz): To study or examine carefully.

conservation (kän sər vā shən): The care and protection of natural resources such as forests and water.

conserve (kən sərɪv): To avoid wasteful or destructive use of something.

dataset (dā tə set): A comprehensive collection of related data organized for convenient access, generally in a computer.

decomposition (dē kəm pō zi shən): The act or process of breaking up, as by decaying or rotting.

hypothesis (hī pä thə səs): (1) An unproven idea that is accepted for the time being and is often tested during a scientific study; (2) An educated guess about the solution to a question or problem based on existing knowledge.

monitor (mä nə tər): To watch, observe, listen to, or check (something) for a special purpose over a period of time.

priority (prī or ə tē): Something that is more important than other things and that needs to be done or dealt with first.

spatial (spā shəl): Of or relating to space and the relationship of objects within it.

sustainable (sə stā nə blē): Of, relating to, or being a method of using a resource so that the resource is not depleted or permanently damaged.

synthesize (sīn thə sīz): To make something by combining different things.

temporal (təm p(ə) rəl): Of or relating to time as opposed to space.

viable (vī ə bəl): Capable of being done or used.

Accented syllables are in **bold**. Marks and definitions are from <http://www.merriam-webster.com>. Definitions are limited to the word's meaning in the article.

Adapted from McKinley, D.C.; Briggs, R.D.; Bartuska, A.M. 2012. When peer-reviewed publications are not enough! Delivering science for natural resource management. *Forest Policy and Economics*. 21: 1-11.



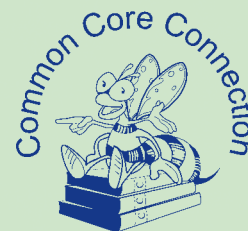
Time Needed

One class period

Materials

(for each student or group of students)

- Device-ive Science Graphic Organizers on page 19



The questions you will answer in this FACTivity are: What are the advantages and disadvantages of having citizen scientists perform data collection and reporting for the community? Would you vote for or against having citizen scientists help with local data collection and reporting in your community?

Methods

You are the manager of your community's water supply. Part of your job is to measure the local reservoir's (re zə **vwärz**) water depth to ensure that enough water is available for your community's needs. A reservoir is a place where water is stored for use (**figure 11**). During the summer when less rain is falling, an employee must measure and record the water level at the same time every day. The employee who performed this work reports to you and provides you with the information.

You have just been told that your budget has been cut and you need to reduce costs. You decide to set up a citizen science project to help you get your job done. You plan to have seven adult citizens measure the water level and record the water depth into an online system. Each of the seven citizens will come once a week, on their assigned day. If the level falls below a certain depth, the citizen scientist must immediately report this information to you.

You want to present this idea to your boss, but you know she will want to know the advantages and disadvantages of having community members serve as citizen scientists. In small groups, complete the following forms. Use correct grammar, spelling, and punctuation when writing in the forms. Following the exercise, each group will give a short presentation to the class.

You will first brainstorm a list of considerations and write these considerations in the following form. These considerations are things that might impact the project's success. Examples include: (1) citizens will be motivated to measure and record accurate levels because they need the water, too; and (2) citizens may not know how to accurately measure and record water depth. Then organize these considerations into advantages and disadvantages.



Figure 11. A reservoir is an area where water is stored for use. Many reservoirs are large, human-made lakes. Photo courtesy of Babs McDonald.

Device-ive Science Graphic Organizer

Group Members: _____

Considerations

Advantages of Having Citizens Test the Water Level

Disadvantages of Having Citizens Test the Water Level

After listening to the advantages and disadvantages identified by all groups, hold a class vote on whether to invite citizens to test your community's water supply level.



FACTivity Extension

Note: You must have online access to do this FACTivity Extension.

Pick one of the citizen science projects listed in the Citizen Science Resources section on page 89. Go to the listed website and explore the project so that you become familiar with it.

How might the same advantages and disadvantages you identified in the FACTivity apply to this citizen science project? What other considerations might apply to the citizen science project?

Natural Inquirer Connections

You may want to refer to these *Natural Inquirer* resources for additional information and FACTivities related to this article:

- “The Morel of the Story” *Natural Inquirer* monograph. This monograph compares the knowledge of local mushroom gatherers with scientific information.
- For more information about ecosystem services, see the *Natural Inquirer* Ecosystem Services edition.



These resources, along with others, can be found at <http://www.naturalinquirer.org/all-issues.html>.

What's in a Name?

This article's title is a play on the word, “divisive.” Divisive means to cause disagreement among people. In this article, device-ive refers to the use of technological devices to conduct citizen science.

Web Resources

Forest Service Citizen Science

<https://www.fs.fed.us/working-with-us/citizen-science>

Federal Citizen Science Resources

<https://www.citizenscience.gov>

Science for Citizens

<https://scistarter.com/>

Student Conservation Association

<http://www.thesca.org>

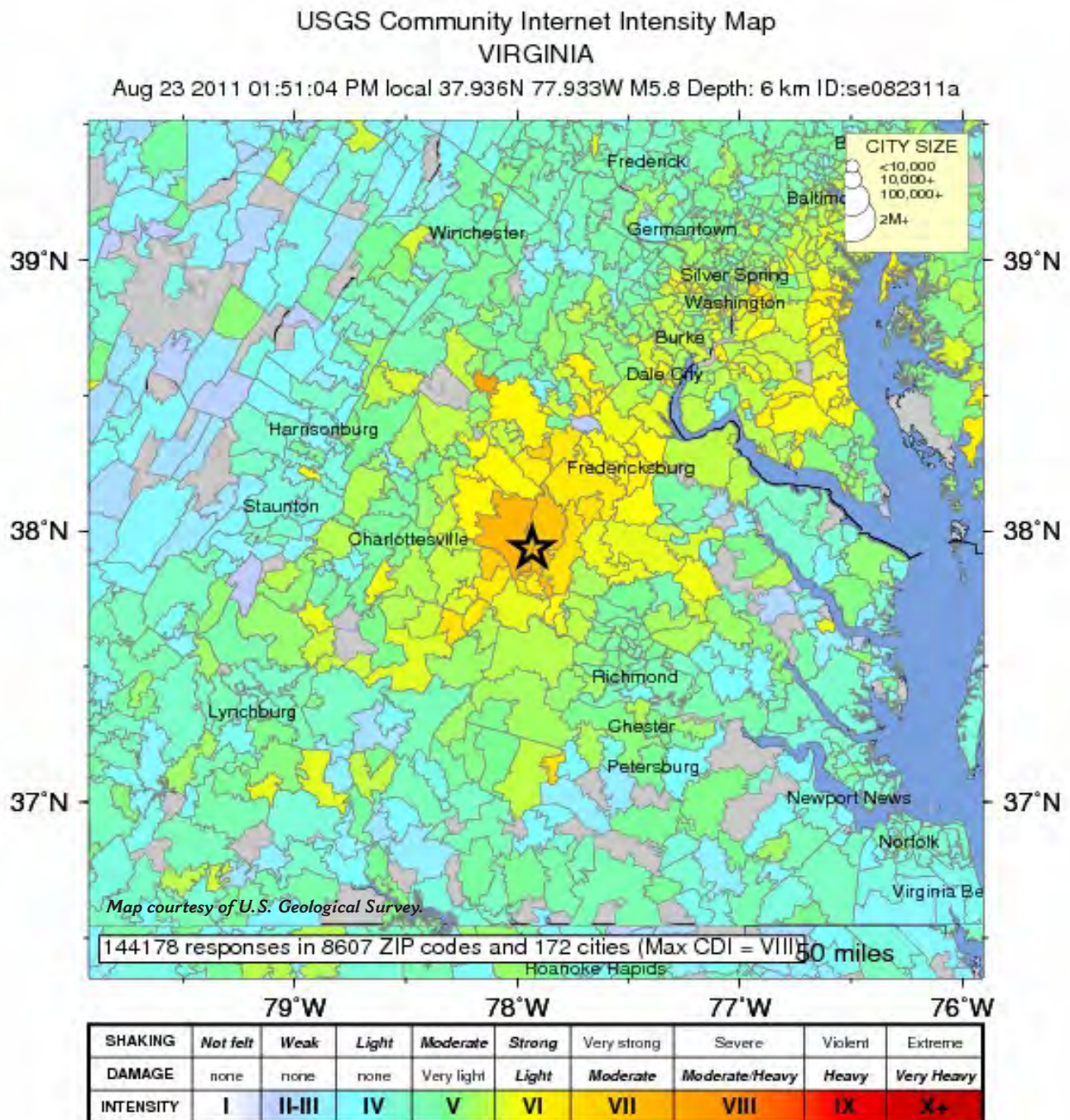


If you are a trained Project Learning Tree educator, you may use “Publicize It!” as an additional resource.



All Over The Map

Investigating the "Did You Feel It?" Citizen Science System



Meet the Scientists

► **Dr. David Wald**, Earthquake Seismologist: My favorite science experience is coming up with new (or even obvious) ways for solving tough problems while doing something unrelated: running, hiking, daydreaming. When an idea or solution pops into my head, it's **invigorating**.

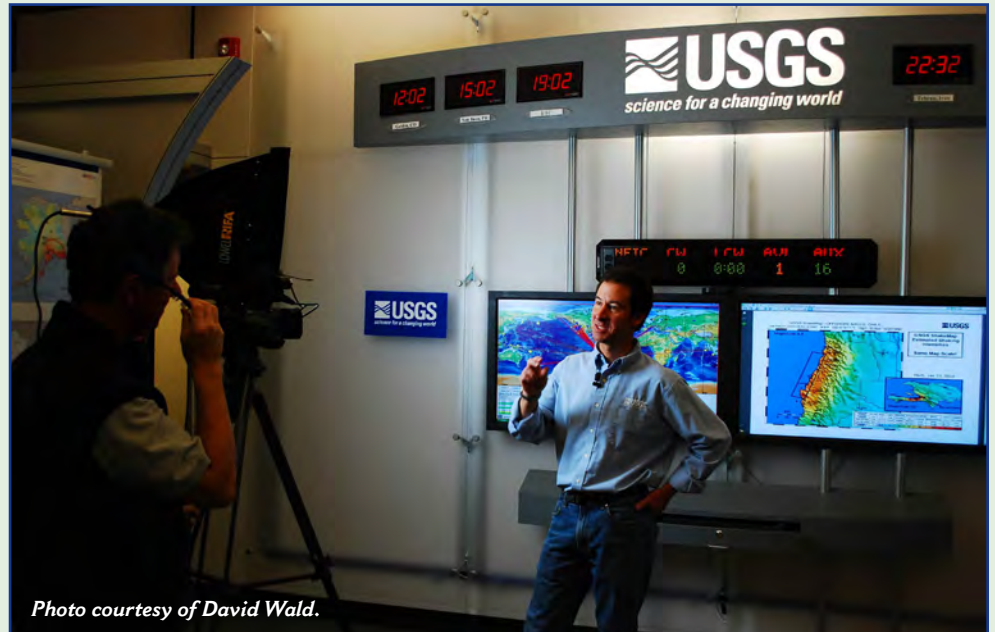


Photo courtesy of David Wald.

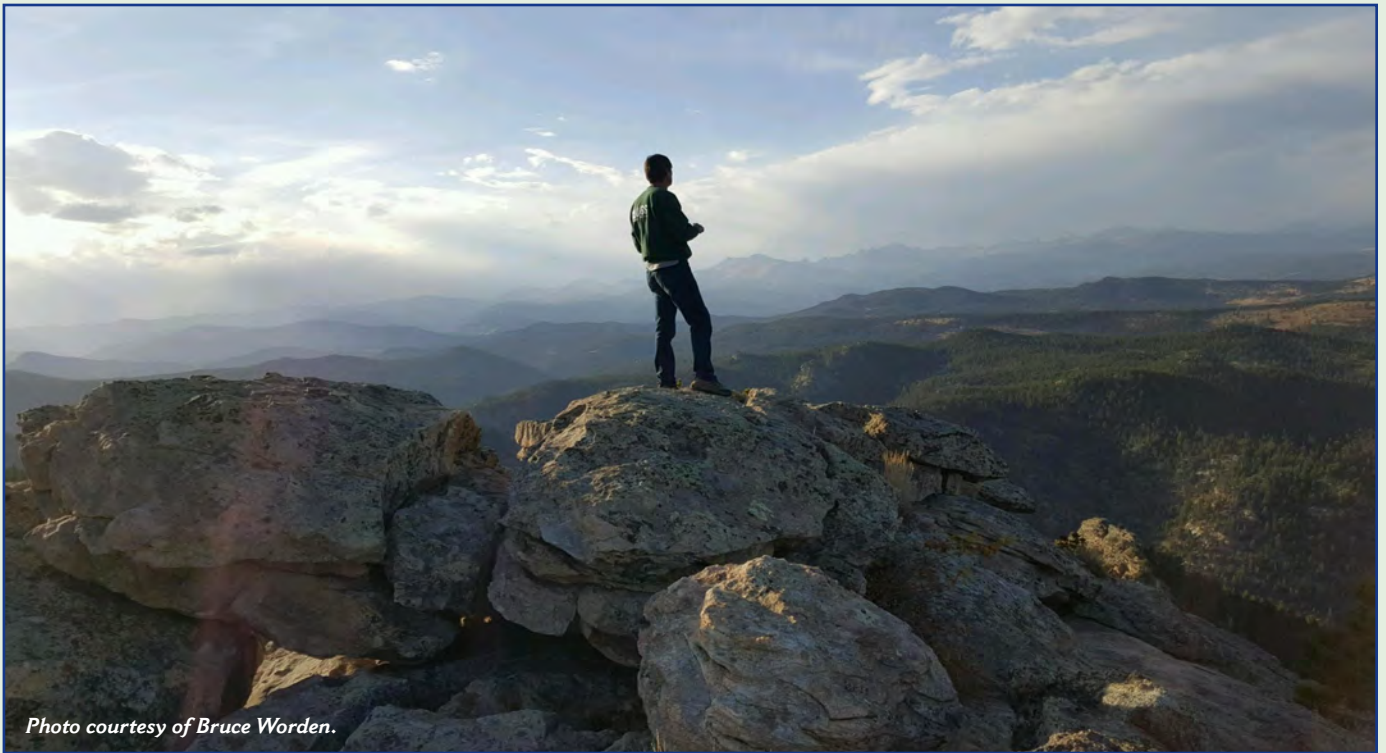


Photo courtesy of Bruce Worden.

▲ **Dr. Bruce Worden**, Earthquake Seismologist: I enjoy bringing data together with theory. Sometimes the data tell you that your idea could be right, and other times you discover that you are wrong. Either way, you've learned something new about the world.

Glossary words are **bold** and are defined on page 34.

What Kind of Scientist Did This Research?

earthquake seismologist: This type of scientist studies earthquakes and the waves (or vibrations) created by earthquakes.

Thinking About Science

Scientists gather, analyze, and evaluate data to solve problems or gain additional information about a topic.

Scientists work in many different areas of the world and study a wide variety of topics. Did you know that you can help scientists with their work? Individuals who help scientists collect data are called citizen scientists. Citizen scientists are valuable because citizen scientists enable scientists to gather more data and cover more areas than the scientists would be able to do by themselves.

Citizen scientists often use the Internet to submit data, and citizen science takes a variety of forms. Examples of some citizen science projects include gathering data about soil, asteroids, weather, plants, **migratory** dragonflies, and earthquakes. Citizen scientists usually have some degree of training in gathering data. Sometimes, however, citizens help with gathering scientific data but have not received training. When this happens, the work they do is referred to as citizen-based science.

The scientists in this study were particularly interested in earthquakes and the data provided by citizen-based science related to earthquakes. To learn about some citizen science and citizen-based science projects, read the Citizen Science Resources on page 89 of this journal or visit <https://www.citizenscience.gov>.



Thinking About the Environment



An earthquake happens when two blocks of earth move past each other suddenly (**figure 1**). The movement of the two blocks of earth causes a release of energy which in turn creates vibrations and movement in the surrounding area. The place at which the two blocks of earth move past each other is called the fault or fault line. Earthquakes typically start deep within Earth. The point on Earth's surface above where the earthquake starts is called the epicenter (**figure 2**).



Figure 1. An earthquake occurs when two blocks of earth move past each other suddenly. Illustration by Stephanie Pfeiffer.

The U.S. Geological Survey is the Federal Government agency that monitors and studies earthquakes. Earthquakes are recorded by instruments called seismographs (**figure 3**).

The first seismographs were used in 1890. Since that time, a seismographic network has been built across the United States called the Advanced National **Seismic** System (**figure 4**).

Number Crunch



For how many decades have seismographs been used?

Figure 2. The **epicenter** is the point on Earth's surface above where the earthquake starts. Illustration by Stephanie Pfeiffer.

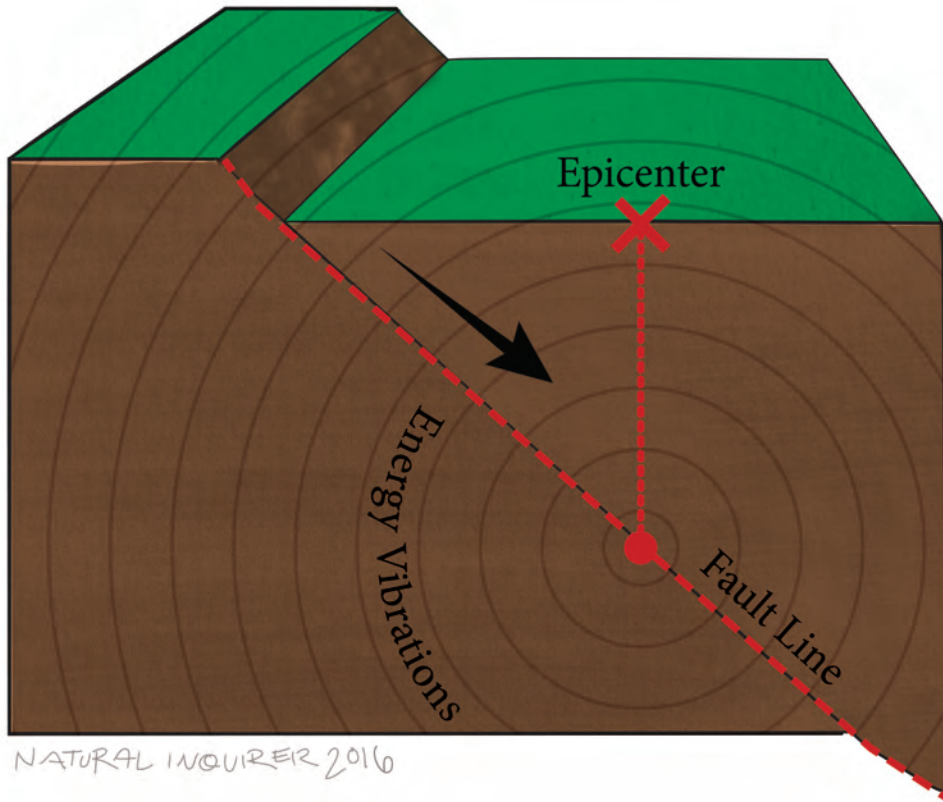
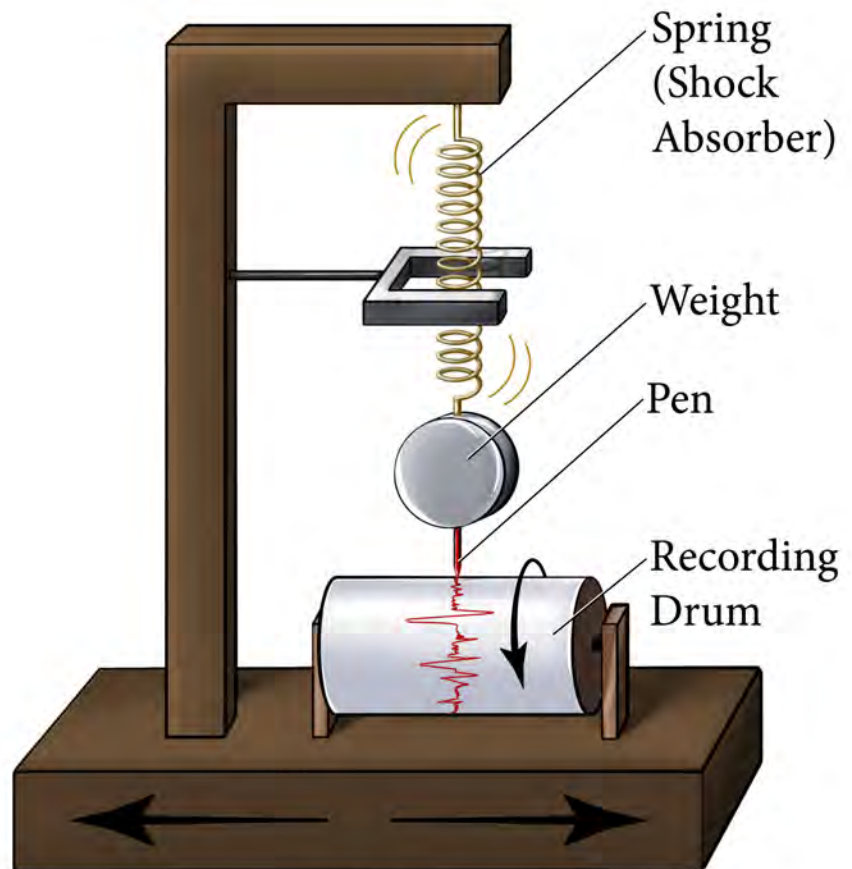


Figure 3. Seismographs are instruments used to detect and record earthquakes. The seismograph has a base that sits firmly on the ground with a heavy weight that hangs free.

When an earthquake occurs, the base of the seismograph moves, but the weight does not move. The spring in the seismograph absorbs the movement instead. The seismograph records the difference in position between the shaking part of the seismograph and the motionless part of the seismograph. Illustration by Stephanie Pfeiffer.



Additionally, a larger, global network called the Global Seismographic Network has locations across the planet (**figure 5**). These two networks of seismographs collect data about the occurrence of earthquakes.

Information from the seismographs help scientists assign a **magnitude** to an earthquake. Magnitude measures the energy released at the source of an earthquake. Another earthquake measurement is called intensity. Intensity is a measurement of the strength of shaking at a certain location; and

an earthquake produces many intensities of shaking at different locations. The Modified Mercalli Intensity Scale is used to measure intensity (**figures 6a and 6b**). The following table gives intensities that are typically observed at locations near the epicenter of earthquakes of different magnitudes.

When an earthquake occurs, scientists want to gather as much data as possible. These data enable scientists and decisionmakers to more successfully respond to and prepare for earthquakes.

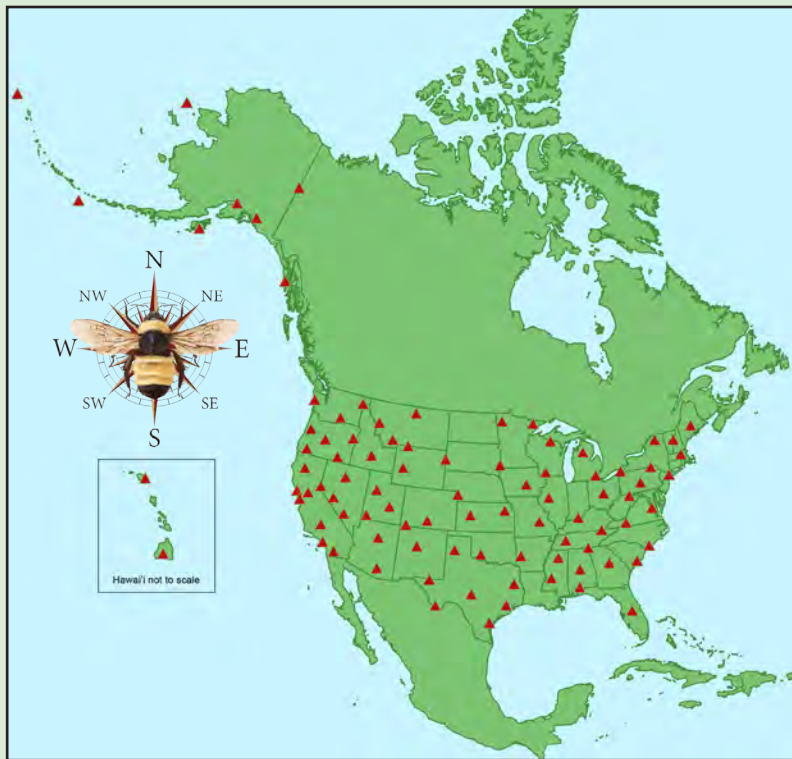
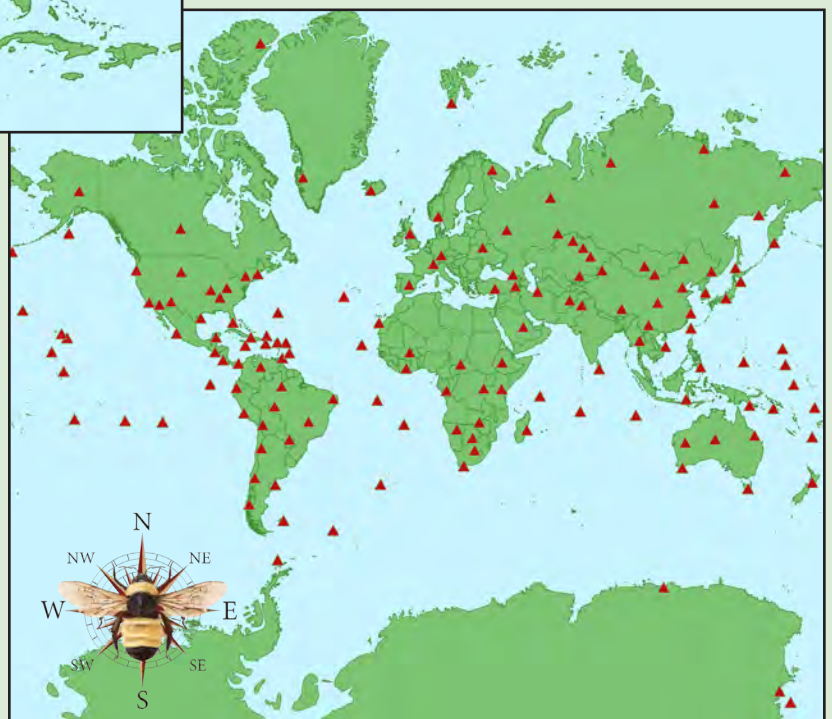


Figure 4. The Advanced National Seismic System has seismic stations across the Nation. Is a station located near where you live? Map by Carey Burda and Stephanie Pfeiffer.

Figure 5. The Global Seismographic Network has locations across the globe. Map by Carey Burda and Stephanie Pfeiffer.



Magnitude	Typical Maximum Modified Mercalli Intensity
1.0 - 3.0	I
3.0 - 3.9	II – III
4.0 - 4.9	IV – V
5.0 - 5.9	VI – VII
6.0 - 6.9	VII – IX
7.0 and higher	VIII or higher

Figure 6a. A comparison of magnitude and intensity measurements for earthquakes.

Intensity	Shaking	Description/Damage
I	Not felt	Not felt except by a very few under especially favorable conditions.
II	Weak	Felt only by a few persons at rest, especially on upper floors of buildings.
III	Weak	Felt quite noticeably by persons indoors, especially on upper floors of buildings. Many people do not recognize it as an earthquake. Standing motor cars may rock slightly. Vibrations similar to the passing of a truck. Duration estimated.
IV	Light	Felt indoors by many, outdoors by few during the day. At night, some awakened. Dishes, windows, doors disturbed; walls make cracking sound. Sensation like heavy truck striking building. Standing motor cars rocked noticeably.
V	Moderate	Felt by nearly everyone; many awakened. Some dishes, windows broken. Unstable objects overturned. Pendulum clocks may stop.
VI	Strong	Felt by all, many frightened. Some heavy furniture moved; a few instances of fallen plaster. Damage slight.
VII	Very strong	Damage negligible in buildings of good design and construction; slight to moderate in well-built ordinary structures; considerable damage in poorly built or badly designed structures; some chimneys broken.
VIII	Severe	Damage slight in specially designed structures; considerable damage in ordinary substantial buildings with partial collapse. Damage great in poorly built structures. Fall of chimneys, factory stacks, columns, monuments, walls. Heavy furniture overturned.
IX	Violent	Damage considerable in specially designed structures; well-designed frame structures thrown out of plumb. Damage great in substantial buildings, with partial collapse. Buildings shifted off foundations.
X	Extreme	Some well-built wooden structures destroyed; most masonry and frame structures destroyed with foundations. Rails bent.

Figure 6b. This figure shows a more complete version of the Mercalli Modified Intensity Scale. Abridged from *The Severity of an Earthquake*, a U.S. Geological Survey General Interest Publication. 1989: 288–913.

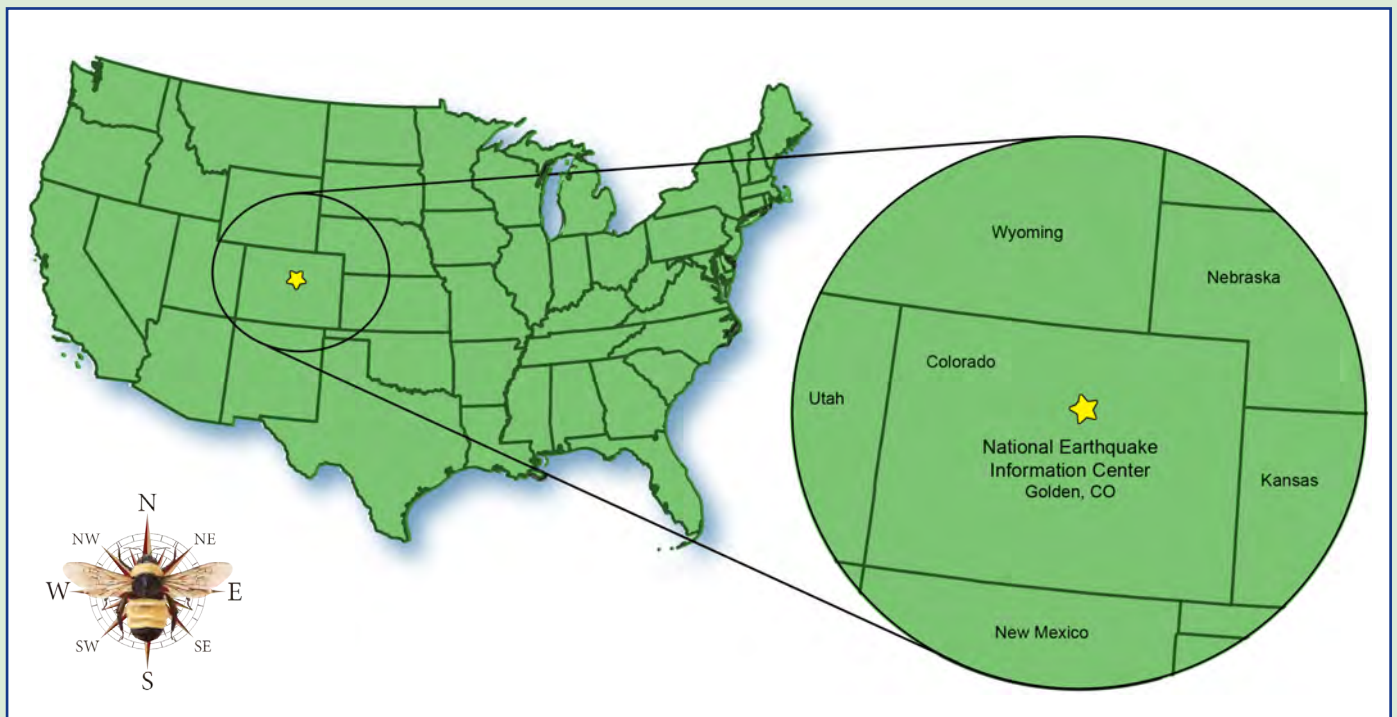
What Is the National Earthquake Information Center (NEIC)?

The National Earthquake Information Center (NEIC) is part of the U.S. Geological Survey and is located in Golden, Colorado. The NEIC has three main missions: (1) to locate and determine the size of an earthquake as quickly as possible, (2) to collect and provide data about earthquakes to scientists and the public, (3) to maintain an active research program to improve understanding and response to earthquakes. The NEIC reports on earthquakes registering a magnitude of about 2.5 or greater in the United States and about 4.5 or greater in other locations around the world. Currently, the NEIC reports on approximately 30,000 earthquakes per year. Based on this number, how many earthquakes occur each day on average?

To learn more about NEIC, visit <http://earthquake.usgs.gov/contactus/golden/neic.php>.



NEIC meeting room. Photo courtesy of David Wald.



The NEIC is located in Golden, Colorado. Map by Carey Burda and Stephanie Pfeiffer.

Introduction

The Advanced National Seismic System is a nationwide network of seismographs. These seismographs gather and record data about a wide variety of earthquakes across the Nation. However, some earthquakes in remote areas are not recorded due to the lack of seismographs in the area. Some scientists wanted to get a more complete description of earthquakes, including their effects and the extent of damage. The scientists thought that information provided by citizens experiencing earthquakes would be useful. To capture this information, the “Did You Feel It?” (DYFI) system was created in 1997.

The DYFI system allows Internet users to report earthquake data when they feel

an earthquake. The data submitted are put into computer programs that create “Did You Feel It?” Maps. The data collected are used to create color-coded maps based on the ZIP Codes. The map colors correspond to the earthquake intensity reported by the DYFI users (**figure 7**). More than 4 million entries have been submitted from 1999 to 2017.

The scientists wanted to know how the DYFI system changed from 1999 to 2013. The scientists wanted to know the advantages and disadvantages of gathering earthquake intensity data through a citizen-based science network. Additionally, the scientists wanted to measure the accuracy and timeliness of the DYFI system data.

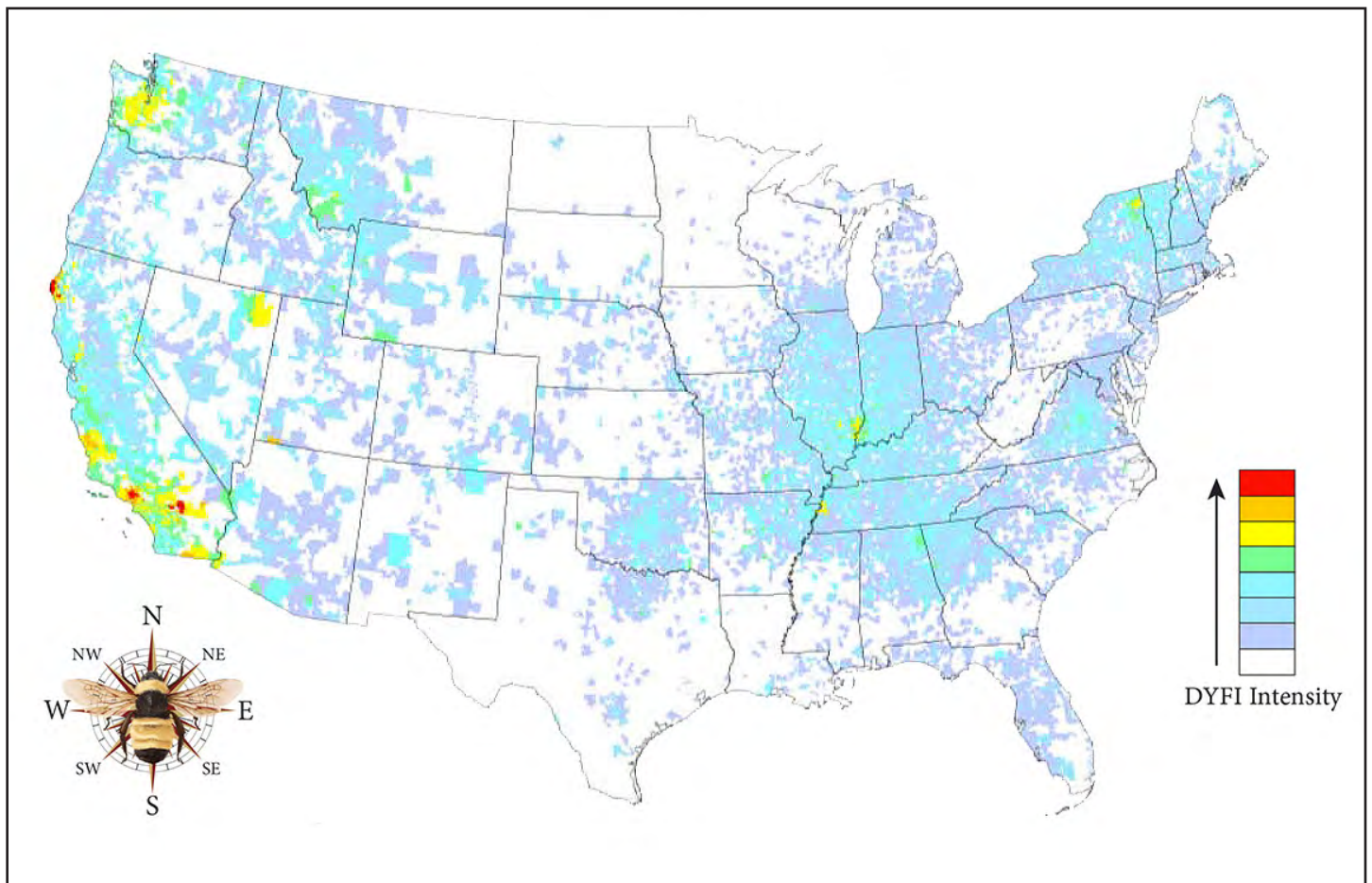


Figure 7. The DYFI map shows data entries from 1999 to 2013. Map courtesy of the U.S. Geological Survey.

Reflection Section



- ✿ In your own words and in the form of a question, explain what the scientists were interested in studying.
- ✿ Based on what you have read so far, provide one example of how the DYFI system allows citizens to participate in science research.

Number Crunch

- ✿ Write out 1.6 million in numeric form.

Methods

The scientists examined more than 10 years of data from the DYFI system. The scientists compared these data to other earthquake maps and data gathered by the U.S. Geological Survey. National Seismic Hazard Maps are produced every 6 years and display potential earthquake ground motions based on differing levels of **probability**. These maps help people understand the probability that earthquake ground motion will occur in certain areas. Earthquake ground motion is how much the Earth shakes in response to the earthquake's seismic waves.

The ground motion probabilities are indicated by different colors on the map. For example, colors on the 2008 map show the levels of horizontal shaking. Horizontal shaking is the ground movement that goes in a horizontal motion. The map shows the chance that in a 50-year period this horizontal shaking will occur (**figure 8**).

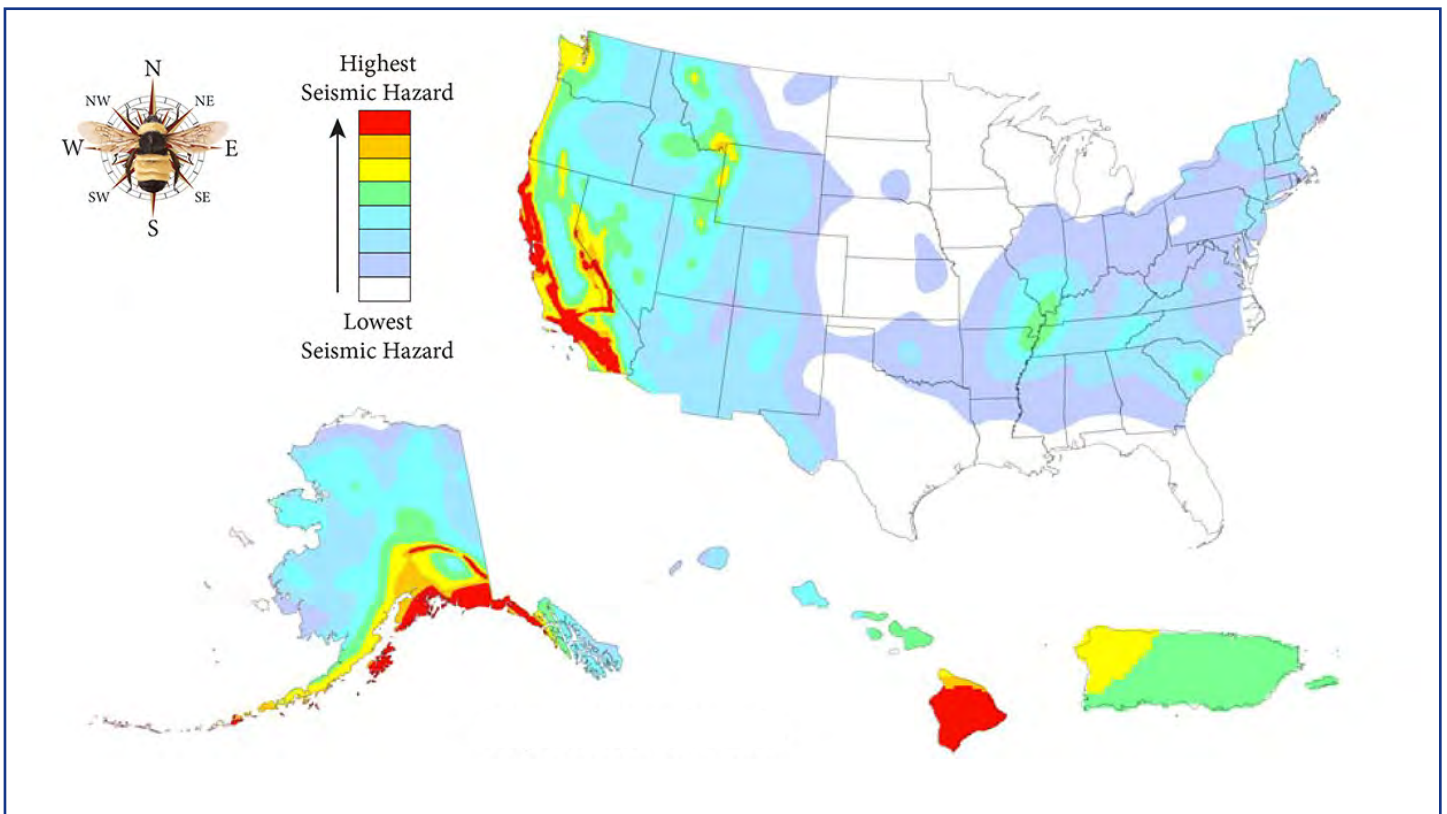


Figure 8. Where do you see the highest levels of probability? Map courtesy of the U.S. Geological Survey.

The scientists compared the 2008 National Seismic Hazard Map to a national map based on 10 years of DYFI data (**figure 9**). Intensity levels are color coded to approximately match each other. The DYFI national map is based on 1.6 million individual entries from more than 25,000 ZIP Codes. The scientists also compared the DYFI data with ShakeMaps (**figure 10**). ShakeMaps are maps that represent the ground shaking produced by an earthquake as recorded on the seismic

instruments. An earthquake produces a wide variety of ground shaking depending upon the ground's distance from the earthquake's epicenter, the rock and soil conditions, and differences in the seismic waves moving through Earth's crust.

The scientists also compared the data from 10 years of DYFI entries to measure the accuracy and timeliness of the data. The scientists used computers and computer software to analyze the data.

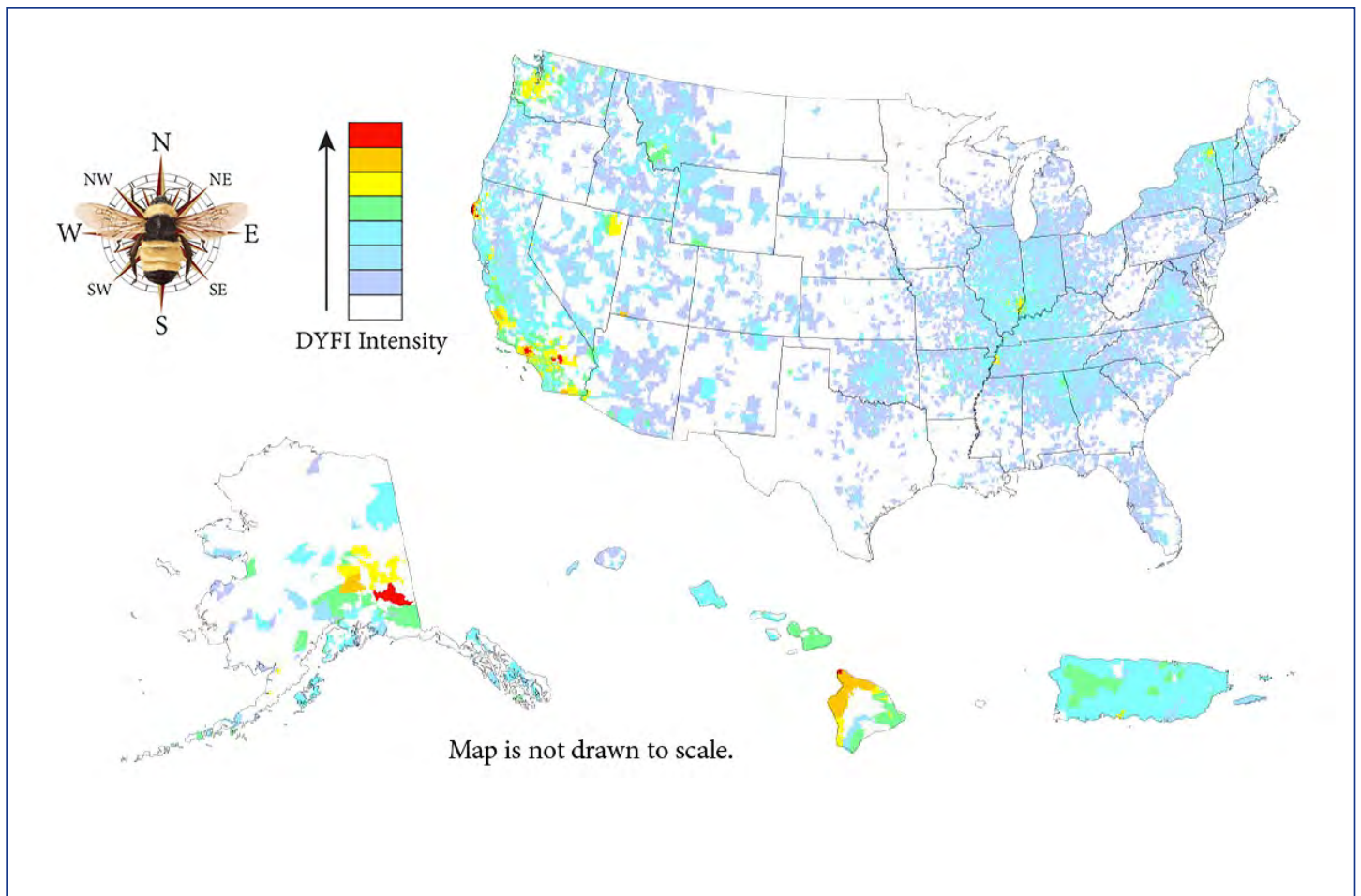


Figure 9. Compare this map to the map in Figure 8. What is one similarity between the maps? What is one difference between the maps? Map courtesy of the U.S. Geological Survey.

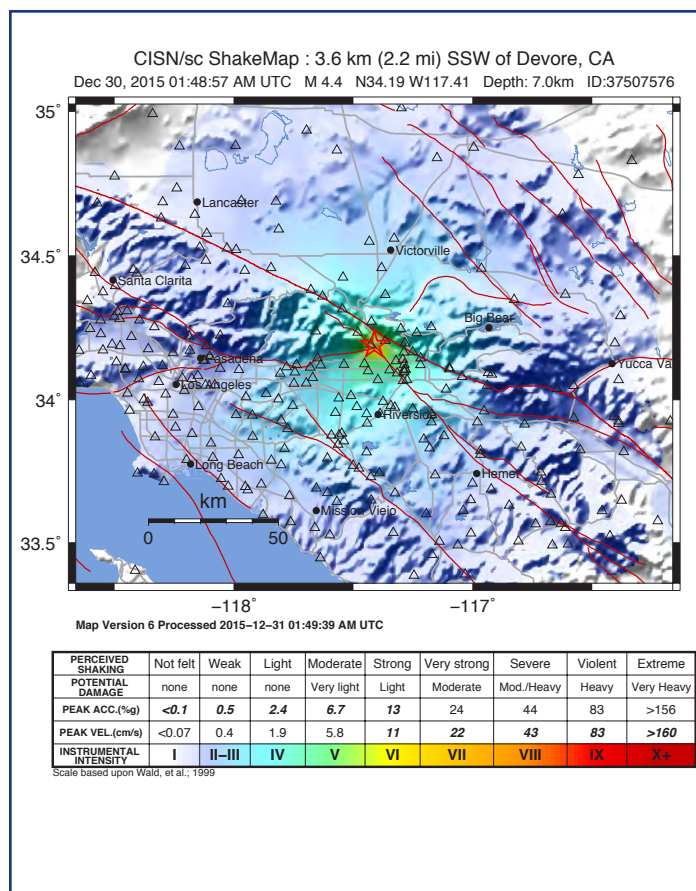
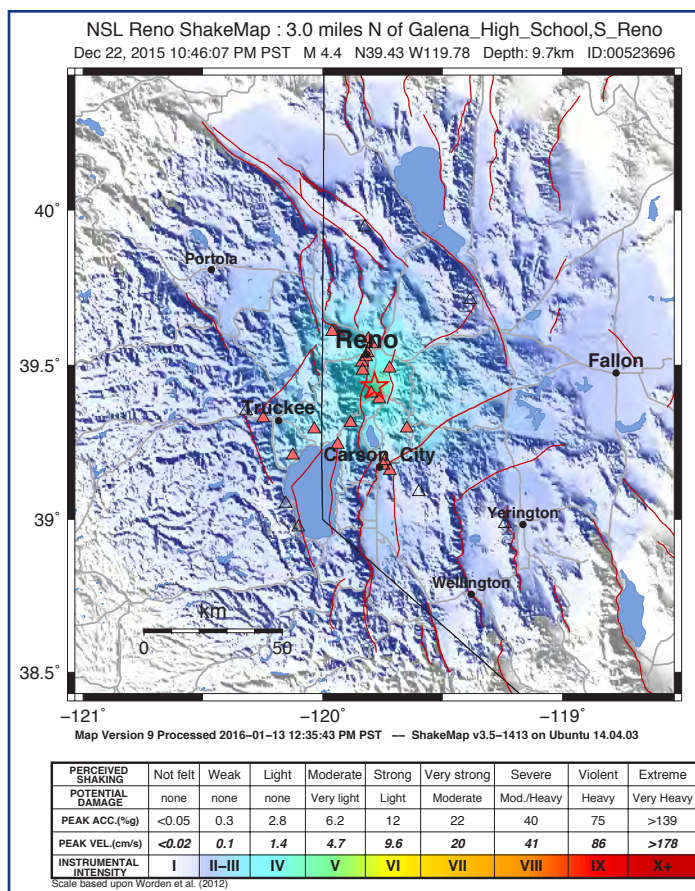


Figure 10. ShakeMaps show the ground shaking produced by an earthquake as recorded by the seismic instruments. Maps courtesy of U.S. Geological Survey.

Reflection Section

- Name one reason you think the scientists were interested in learning about the timeliness and accuracy of the data from the DYFI system. Why do you think this reason is important?
- What do you think are one or two advantages of comparing different maps for earthquake data?

Findings

Before the DYFI system, collecting shaking intensity information from citizens in an area impacted by an earthquake required a great deal of effort and time. The data weren't available until long after the earthquake occurred, and the amount of data was relatively small and sparse. Because of the immense effort required to collect shaking data, intensity maps using the Modified Mercalli Intensity Scale were rarely made for earthquakes with a magnitude of less than 5.5.

DYFI has changed all that! Since DYFI makes collecting the data fast and easy, the scientists found that they can collect information for earthquakes with any magnitude, as long as it was felt. Previously, in areas where there were no seismic instruments close by, some small-magnitude earthquakes were not recorded at all. The scientists found that, based on the data provided through DYFI, even earthquake events with less than a magnitude 2.0 are routinely reported. They also found that the DYFI data are timely. The

scientists calculated that, after an earthquake, approximately 62,000 responses are processed in an hour, or around 1,000 responses per minute!

DYFI maps are created not only for earthquakes, but also for other events that cause shaking and vibrations. These other events include mining events and other explosions, **supersonic** aircraft flights, and **bolides**.

Additionally, the DYFI data accuracy is high. The scientists found that the large amount of data that is collected through DYFI provides more accurate information overall. The large amount of data could be compared and averaged, and any responses that seemed out of the ordinary could be discarded.

The quality and quantity of DYFI data, however, ultimately depends on how many people experience an earthquake and how many have access to the Internet. Areas with large populations and easy access to the Internet provide better quality and greater quantities of data. The scientists also found that DYFI data

from citizen scientist reports usually agree with the ShakeMap data recorded by seismic instruments.

Reflection Section



- ✦ The scientists found that the data were of better quality in areas with large populations and easy access to the Internet. Why do you think an area with a large population may have a better quality of data?
- ✦ Now that you have read about what the scientists found in their study of the DYFI system, name one advantage of citizen-based science.

What Is a Bolide?

A bolide is an **astronomical** word for exceptionally bright meteors that can be seen over a wide area. Some people also refer to bolides as fireballs. For more information on bolides, visit the National Aeronautics and Space Administration Near Earth Object Program website at <http://neo.jpl.nasa.gov/fireballs/>.

Photo courtesy of <http://www.iStockphoto.com>



Out of This World Science!

People have become accustomed to using the DYFI system for events that cause shaking. People are so used to reporting to the DYFI system that a descending space shuttle flying over Los Angeles caused enough entries to create its own DYFI page. The DYFI users provided so much data that an accurate map of the re-entry **trajectory** of the spacecraft could be created!



Photo courtesy of Bill Ingalls, National Aeronautics and Space Administration.



Citizen Science Connections

The Did You Feel It? (DYFI) system was created to gather information about earthquakes from the people who experience the earthquakes. Using the Internet, scientists can get information quickly about what citizens experience and the effects of earthquakes. Scientists who study earthquakes combine the citizen-based science data from DYFI with state-of-the-art data collection technology.

Did You Feel It? lets citizen scientists:

- Search and view data on earthquakes around the world;
- Report earthquake events in their location;
- Learn about the science of earthquakes.



Did You Feel It? is a project of the U.S. Geological Survey. The DYFI system has collected nearly 3 million data points from citizen scientists since 1997. For more information about the DYFI system, visit <https://earthquake.usgs.gov/data/dyfi>.

Discussion

With the DYFI system, U.S. Geological Survey scientists said that they can now monitor and collect data on all felt and reported earthquakes. The DYFI system also provides other benefits. The scientists found that the DYFI system helps educate the public. The system provides a human perspective on an earthquake and creates data that scientists can use to help understand earthquakes better.

The DYFI system also provides emotional support to people experiencing an earthquake. The system gives citizens the opportunity to share and confirm their experiences with each other. The DYFI system provides high-quality and timely data about earthquakes. This information allows scientists to better understand and respond to earthquake events.

Additionally, the scientists found limitations to the DYFI system. They found that the highest rates of response came from areas with large populations, easy Internet access, and a lack of significant damage and power outages. Therefore, the DYFI system may lack entries from areas harder hit by earthquakes.

These missing data would be important for better understanding an earthquake. However, the main purpose of the DYFI system is to provide scientists with more data to evaluate earthquakes after they have occurred. The DYFI system has provided scientists and the public with more data about earthquakes. Moreover, these data are provided in a timely manner.



Reflection Section

- ❦ U.S. Geological Survey scientists said that they can now monitor and collect data on all felt and reported earthquakes. Why do you think this may be useful to scientists and the public?
- ❦ Scientific research often exposes advantages and disadvantages of programs or topics being studied. One of the main disadvantages of the DYFI system is that the system is not able to get a lot of entries from areas harder hit by earthquakes. The scientists in the research paper discuss both the advantages and disadvantages of the DYFI system. Why do you think it is important to examine a system's advantages and disadvantages?

Glossary

accustomed (ə kəs təmd): Being in the habit or custom.

astronomical (as trə nă mi kəl): Of or relating to astronomy, which is the scientific study of stars, planets, and other objects in outer space.

bolide (bō līd): A large meteor or fireball; especially, one that explodes.

invigorate (in vi gə rāt): To cause (something) to become more active and lively.

magnitude (mag nə tūd): A number that shows the power of an earthquake.

migratory (mī grə tōr ē): Having a characteristic of moving from one place to another on a periodic basis.

probability (pră bə bi lə tē): A measure of how often a particular event will happen if something (such as tossing a coin) is done repeatedly.

seismic (sīz mīk): (1) Of, subject to, or caused by an earthquake; (2) Of or relating to an earth vibration caused by something else (as an explosion or the impact of a meteorite).

supersonic (sü pər să nīk): Faster than the speed of sound.

trajectory (trə jek t(ə-)rē): The curved path along which something (such as a rocket) moves through the air or through space.

Accented syllables are in **bold**. Marks and definitions are from <http://www.merriam-webster.com>. Definitions are limited to the word's meaning in the article.

Adapted from Wald, D.J.; Quitoriano, V.; Worden, B.; Hopper, M.; Dewey, J.W. 2011. USGS "Did You Feel It?" Internet-based macroseismic intensity maps. *Annals of Geophysics*. 54(6): 688-707.

FACTivity

Time Needed

One class period

Materials

(for each student or group of students)

- Two earthquake data tables
- Graphing paper
- Pencils
- Highlighters

The questions you will answer in this FACTivity are: How do the number of earthquakes from the 1990s compare to the number of earthquakes in the 2000s? How do the magnitudes of the earthquakes compare between the two time periods?

Methods

Look at the two earthquake data tables on page 35. Highlight the row in each table for

total earthquakes. Create two bar charts and compare total earthquakes for the 1990–1999 time period with the 2000–2009 time period. Here are a few questions to think about:

- Which year had the most earthquakes during 1990–1999?
- Which year had the most earthquakes during 2000–2009?
- Look closely at the two data tables. Circle magnitudes with the highest occurrence of earthquakes. Is the magnitude you highlighted the same in each time period?
- Do you think that the two time periods are similar or not? Why do you think this? Use evidence from the tables to help support your thinking.



Number of Earthquakes in the United States for 1990–1999
Located by the U.S. Geological Survey National Earthquake Information Center

Magnitude	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
8.0 to 9.9	0	0	0	0	0	0	0	0	0	0
7.0 to 7.9	0	NA	2	0	1	0	2	0	0	NA
6.0 to 6.9	2	4	15	9	4	6	4	6	3	6
5.0 to 5.9	64	49	72	62	64	45	100	63	62	50
4.0 to 4.9	284	242	404	270	333	350	612	362	411	352
3.0 to 3.9	626	713	1717	1119	1543	1058	1060	1072	1053	1398
2.0 to 2.9	414	559	998	1009	1196	822	654	759	742	814
1.0 to 1.9	1	3	5	7	2	0	0	2	0	0
0.1 to 0.9	0	0	0	0	0	0	0	0	0	0
No Magnitude	877	599	368	457	444	444	375	575	508	381
Total Earthquakes	2268	2171	3581	2933	3587	2725	2807	2839	2779	3003
NA = Not Applicable										

Number of Earthquakes in the United States for 2000–2009
Located by the U.S. Geological Survey National Earthquake Information Center

Magnitude	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
8.0 to 9.9	0	0	0	0	0	0	0	0	0	0
7.0 to 7.9	0	1	1	2	0	1	0	1	0	0
6.0 to 6.9	6	5	4	7	2	4	7	9	9	4
5.0 to 5.9	63	41	63	54	25	47	51	72	85	58
4.0 to 4.9	281	290	536	541	284	345	346	366	432	288
3.0 to 3.9	917	842	1535	1303	1362	1475	1213	1137	1486	1492
2.0 to 2.9	660	646	1228	704	1336	1738	1145	1173	1573	2379
1.0 to 1.9	0	2	2	2	1	2	7	11	13	26
0.1 to 0.9	0	0	0	0	0	0	1	0	0	1
No Magnitude	415	434	507	333	540	73	13	22	20	14
Total Earthquakes	2342	2261	3876	2946	3550	3685	2783	2791	3618	4262

Technology FACTivity



Time Needed

One class period

Materials

(for each student or group of students)

- Computers with Internet access
- Two maps chosen from <http://earthquake.usgs.gov/earthquakes/byregion/> (Recommended: one map from the East Coast of the United States and one from the West Coast of the United States)
- 2014 National Earthquake Hazard Map http://earthquake.usgs.gov/hazards/hazmaps/conterminous/2014/images/HazardMap2014_lg.jpg

The questions you will answer in this FACTivity are: How does the seismic data compare between different States? What is the seismic activity like in your State? What does the 2014 National Earthquake Hazard Map tell you about the seismic hazard in your State?

Methods

On a computer, go to <http://earthquake.usgs.gov/earthquakes/region.php>. Select one State from the East Coast and one from the West Coast. Compare the map data between the two States. Answer these questions:

1. What are the main differences between the maps from each State?
2. What is one similarity between the maps?
3. Based on the State maps you are looking at, which State would you say has the most seismic activity? Why?
4. Now, take a moment to look at your own State map. Also, go to http://earthquake.usgs.gov/hazards/products/conterminous/2014/HazardMap2014_lg.jpg and look at the 2014 National Earthquake Hazard Map. Specifically, look at your State. List three things you notice on the maps about your State. What surprises you about the seismic activity in your State?

Web Resources

Did You Feel It?

<https://earthquake.usgs.gov/data/dyfi>

U.S. Geological Survey Earthquake Hazards Program

<https://earthquake.usgs.gov/>

U.S. Geological Survey Earthquakes for Kids

<https://earthquake.usgs.gov/learn/kids/>

Rock n' on Shakey Ground by U.S. Geological Survey

<https://earthquake.usgs.gov/learn/kids/RockShakeyGround.pdf>

Advanced National Seismic System

<https://earthquake.usgs.gov/monitoring/anss/>

National Aeronautics and Space Administration Sonic Booms

<https://www.nasa.gov/centers/armstrong/news/FactSheets/FS-016-DFRC.html>



Lion in Wait

A full-page underwater photograph showing two divers. The diver on the left is wearing a black wetsuit with a yellow stripe and 'sequest' and 'Lassit' logos. The diver on the right is wearing a black wetsuit with 'APRO' and 'Lassit' logos. They are both wearing masks and are focused on a small, striped lionfish held in the diver's hands. Bubbles are visible around the divers' heads, and the background shows a sandy ocean floor with some seaweed.

***How Citizens Helped
Scientists Identify a Rapid
Invasion of Lionfish***

Photo courtesy of Lad Akins.

Meet the Scientists



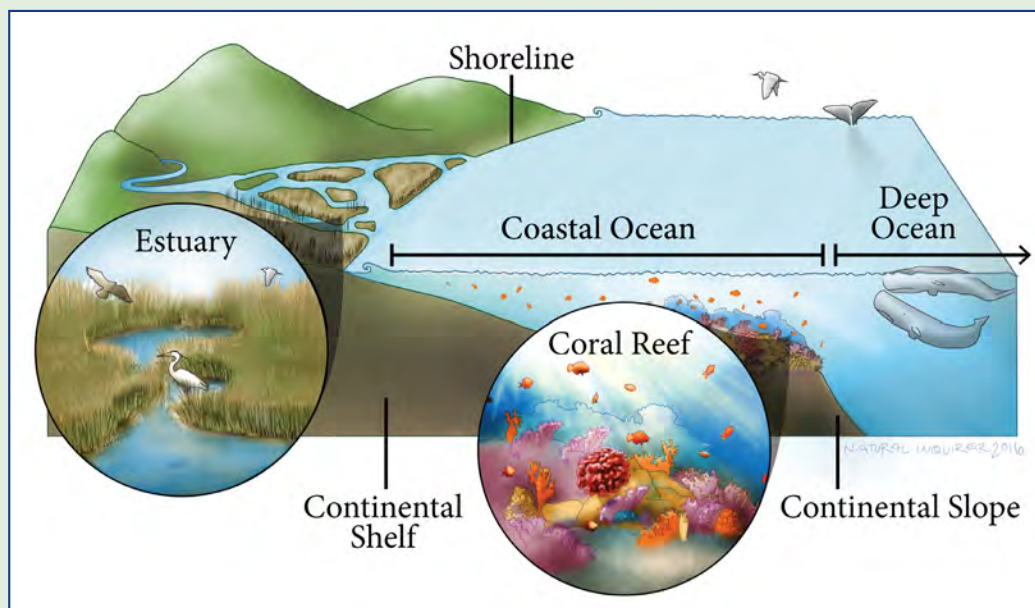
◀ **Dr. Steven Scyphers**, Sustainability Scientist: My favorite science experience is meeting and hearing stories directly from commercial fishers and other residents of coastal communities. Commercial fishers are people who fish as a part of their job.

As scientists, we spend quite a bit of our time designing surveys and experiments to better understand our coasts. However, the amount of time that we are able to spend on the water is often far less than folks who work or live near the coast. For example, a waterfront homeowner showed us his homemade boat powered by a bicycle. He

peddles his boat around the bay to visit neighbors by water.

Scientists increasingly recognize the value of local citizens' knowledge and experiences for our efforts to understand coastal oceans. For example, we were able to obtain photographs taken by the coastal resident who peddles his bicycle-powered boat. From his photographs, we were able to scientifically document how recent hurricanes had affected coastal marshes and fishing vessels. Experiences like these continually remind us why talking with people in coastal communities is important for our science. It is also a lot of fun!

What Is a Coastal Ocean?



A coastal ocean is the strip of ocean from the outer continental shelf to the **estuaries** (es chə wer ēs) close to the shore. Although coastal oceans represent only 7 percent of the ocean's surface worldwide, they are the richest in marine life of all ocean areas. With an estuary's mix of fresh and salt water, estuaries are some of the most productive ecosystems on Earth. Illustration by Stephanie Pfeiffer.

Meet the Scientists

► **Lad Akins**, Director of Special Projects: My favorite science experience is working with nonscientists to answer scientific questions. Many students, SCUBA divers, and interested members of the general public are helping to address issues like the lionfish invasion.

Some of these people have first-hand knowledge to share, such as the underwater observations from SCUBA divers. Others have time, money, or energy to donate to research projects. One thing all of these people have in common is passion for helping to keep our environment healthy.

I feel satisfied when I am able to help coordinate citizen scientists' energies and expertise to address a problem. We can't always rely on others to fix problems for us. Therefore, it is important to pick a cause, take a stand, and help address issues by being active. The Reef Environmental Education Foundation's motto captures that idea. Our motto is: Explore. Discover. Make a Difference. In this photo, I am close to an Indo-Pacific lionfish. You will soon learn why I am wearing a glove!



Photo courtesy of Lad Akins.

What is SCUBA?

SCUBA's name came from its purpose. SCUBA is a self-contained underwater breathing apparatus. Its purpose is to give divers the ability to breathe underwater. Lad Akins is using SCUBA gear to swim close to the lionfish in the photo.

Glossary words are **bold** and are defined on page 53.

Meet the Scientists



Photo courtesy of David Hay Jones.

► **Dr. Pam Schofield, Fishery Biologist:** So far, my favorite science experience has been living and working in Uganda, East Africa, where I studied the effects of nonnative fishes on the Lake Victoria ecosystem. Uganda is a beautiful country full of amazing wildlife.

I lived very simply in Uganda—with no running water or electricity. Living simply taught me that much of what we think we need in life we really don't need. The people I met in Uganda were incredibly kind and friendly, and I never would have completed my research without their generosity and guidance.



Photo courtesy of Pam Schofield.

◀ **Dr. Charles Martin, Senior Field Ecologist:** My favorite science experience is answering questions about nature. My curiosity about how the natural world works, and how humans have changed the world, drives my scientific research program. I love the creativity involved in asking new questions and figuring out new and unique ways of finding the answers. I feel satisfied with knowing that the science I participate in contributes to a greater understanding of our natural ecosystems. This science also affects the decisions we make to conserve our planet.



Photo courtesy of Charles Martin.

What Kinds of Scientists Did This Research?

director of special projects: This scientist works in a variety of areas and directs unusual projects. At the Reef Environmental Education Foundation, this scientist also conducts scientific research, trains others, and works with citizen scientists.

fishery biologist: This scientist studies fish and how the environment and other outside forces affect fish throughout their life cycle.

marine fisheries ecologist: This scientist studies ocean and coastal marine environments to understand the relationship of fish and other living organisms with each other and the nonliving environment.

senior field ecologist: This experienced scientist conducts field studies to understand the relationship of living things with each other and the nonliving environment.

sustainability scientist: This scientist studies the relationships between human, environmental, and engineered systems. This scientist works to understand and develop solutions to problems that threaten the long-term health of life on Earth.



Thinking About Science

The Gulf of Mexico is a large body of salt water along the Southeastern United States (**figures 1 and 2**). Take a moment to look at how much area is covered by the Gulf of Mexico. The Gulf of Mexico is larger than the combined States of Texas, New Mexico, Arkansas, and Louisiana.



Figure 1. The Gulf of Mexico is a body of salt water along Mexico's east coast, around the east and north coasts of parts of Central America, along the U.S. Gulf Coast, along the west coast of Florida, and in western Cuba. The Gulf of Mexico covers a surface area of 579,153 square miles (1.5 million square kilometers). Maps by Carey Burda and Stephanie Pfeiffer.

Number Crunch

 Write out 1.5 million in numeric form.



Figure 2. The Gulf of Mexico near Pensacola, Florida. Photo courtesy of Babs McDonald.

Think about trying to figure out whether a particular species of marine fish is swimming in the Gulf of Mexico. Now think about trying to figure out how many of these fish are swimming in the Gulf of Mexico, and where they are swimming. This identification and counting is a challenge for marine scientists. The Gulf of Mexico covers a large area, and fish and other marine animals are constantly moving. In addition, seeing large areas under the water's surface can be difficult.

Citizens, and in particular people engaged in outdoor recreation, may be visiting areas far away from other people. Often, these people have opportunities to observe, count,

and report what they have observed. By doing this, they can help scientists because scientists cannot be everywhere. SCUBA divers, for example, may dive in areas where scientists might not be.

The scientists in this study were interested in identifying how many of a particular fish species were swimming in an area of the Gulf of Mexico. The scientists wanted to compare the numbers reported by recreational SCUBA divers with the numbers reported by other methods for identifying and counting marine fish. Recreational SCUBA divers are people who use SCUBA gear to dive and swim under water for pleasure.

Thinking About the Environment



You may have heard the phrase, “The only constant is change.” This phrase means that most things on Earth change over time. Think about the world around you. Does this statement seem true to you?

Some scientists are changing their understanding of invasive species. Invasive species are species that are not **native** to the place they live and are likely to cause harm to the environment, the economy, or human health. Humans have moved many plant and animal species to new areas. In some cases, the movement of species has been accidental, and in other cases, it has been on purpose. In many instances, invasive species have caused ecosystems to change so much that native species are unable to thrive in the ecosystem.

Invasive plant and animal species rapidly reproduce in new habitats. Some scientists have noticed situations, however, in which invasive species do not cause the harm to these new habitats that might be expected. These invasive species seem to fill an ecological role in an ecosystem. For example, in the Western United States, an invasive tree provides habitat for an **endangered** bird species. In another situation, native Hawaiian flowers are pollinated by an invasive bird species where native pollinators no longer live. Invasive species might especially fill ecological roles where humans have destroyed native habitat.

Some scientists are expanding their view of invasive species. In some instances, for example, everything possible should be done to reduce the harm caused by an invasive species. Native ecosystems should be preserved if possible. In other instances, we should realize that invasive species are creating new ecosystems.

As you can see, scientific thinking can change as scientists observe the world around

them. Think of another example of when scientific thinking changed as a result of new observations. Think of an example of when your own thinking changed as a result of new observations. Do you think your thinking will continue to change? Why?

Read the *Natural Inquirer* Hawai'i-Pacific Islands edition to learn more about plants and animals in Hawai'i.



Introduction

Over the past decade, humans have introduced two species of Indo-Pacific lionfish (*Pterois volitans* and *Pterois miles*) into the Atlantic Ocean (**figures 3a and 3b**). These species have spread into the northwestern Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico (**figure 4**). These fishes' native ecosystem is the Indo-Pacific region (**figure 5**). These fishes have been seen in a wide range of Atlantic marine habitats, including coral reefs, hard bottoms, seagrass meadows, mangroves, and oyster reefs (**figure 6**). Sightings in different habitats mean that Indo-Pacific lionfish are found across a wide area, making it difficult to track their expanding numbers.

Marine scientists use established methods to monitor the presence of different fish species in marine ecosystems. These methods include the use of underwater cameras and underwater remotely operated vehicles (ROVs) (**figure 7**). In recent years, scientists have also provided online opportunities for citizens to report fish and other marine sightings. Lad Akins has also developed a method to tag lionfish (**figure 8**). When a lionfish is tagged, its movements can be tracked.

In this research, the scientists wanted to compare the different ways that information is

collected about Indo-Pacific lionfish in an area of the Gulf of Mexico. In particular, the scientists wanted to compare observations and sightings of Indo-Pacific lionfish by recreational SCUBA divers with scientifically taken photographs and ROV videos.



Figures 3a & 3b. Indo-Pacific lionfish are colorful fish with **venomous** spines that protect them from **predators**. This fish eats smaller fish and **invertebrate** marine animals such as shrimp. Lionfish can live for decades. Photos courtesy of Lad Akins.

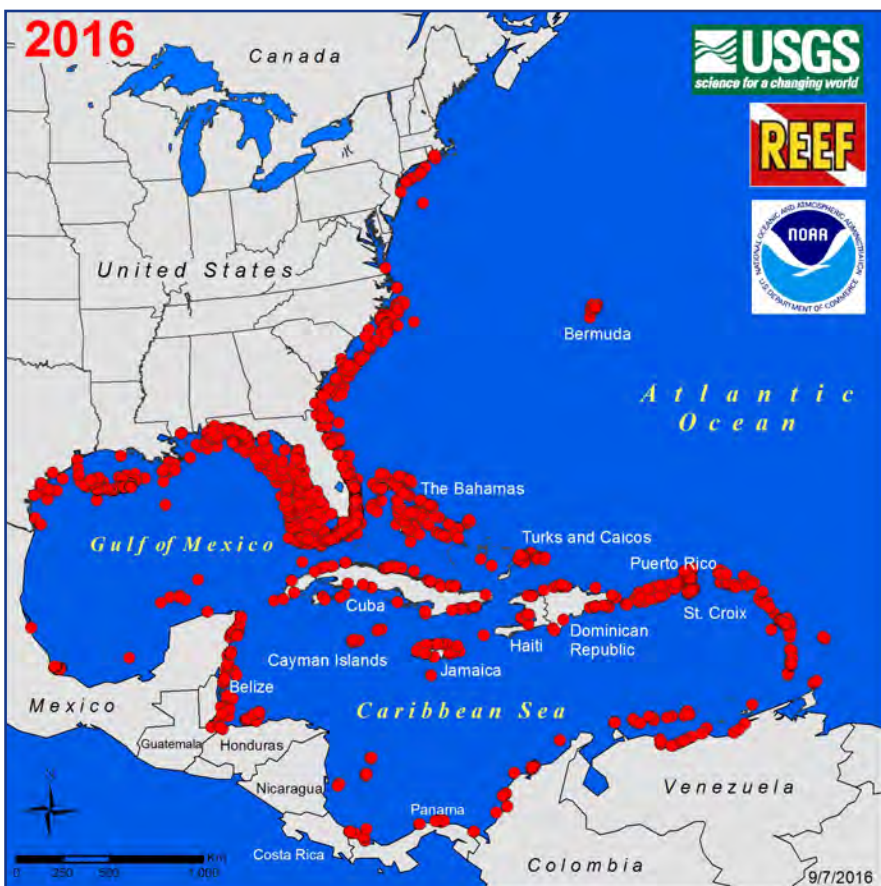


Figure 4. Indo-Pacific lionfish, originally found in the Indo-Pacific region, have been seen in the northwestern Atlantic Ocean, the Caribbean Sea, and the Gulf of Mexico. The red dots on the map indicate sightings of lionfish. Map courtesy of Pam Schofield.



Figure 5. The native habitat of lionfish is the Indo-Pacific region, which includes the Indian Ocean, the western and central Pacific Ocean, the seas of Indonesia which connect those two oceans, and the Red Sea. Map by Carey Burda and Stephanie Pfeiffer.

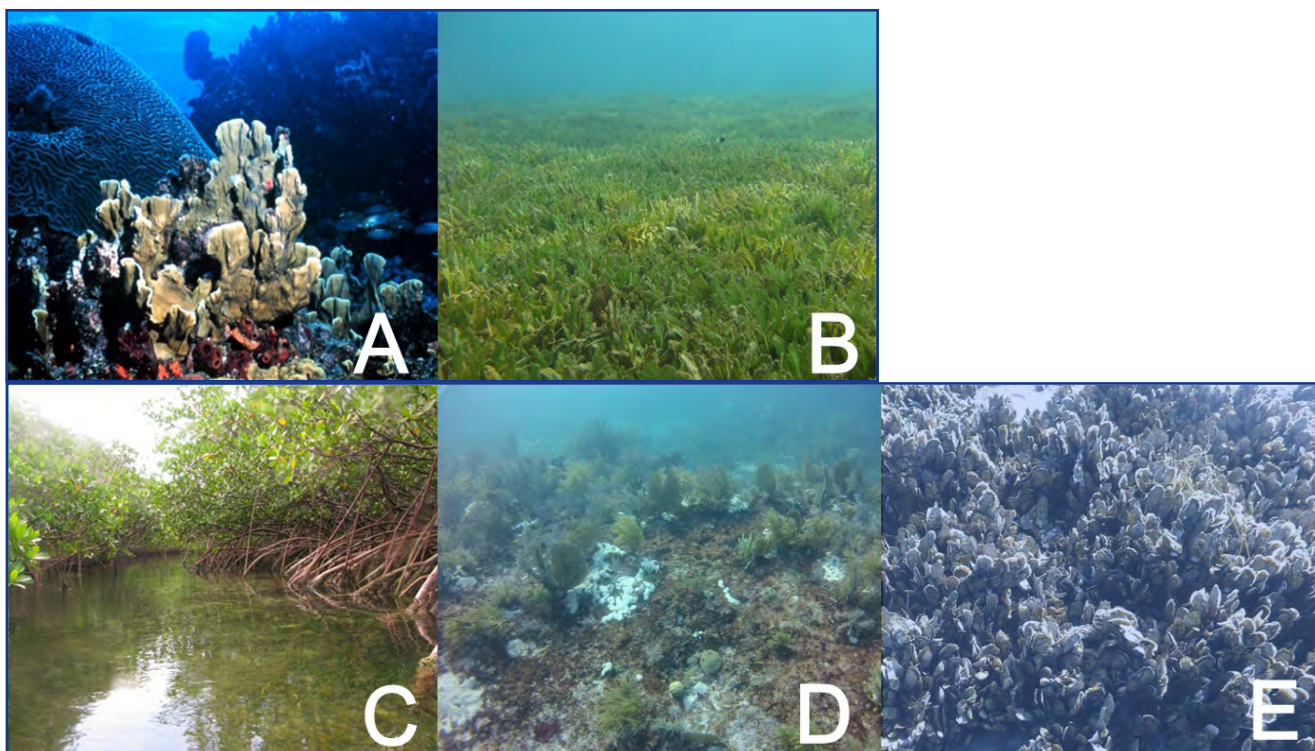


Figure 6. Indo-Pacific lionfish have been seen in coral reefs (A), seagrass meadows (B), mangroves (C), hard bottoms (D), and oyster reefs (E), among other habitats. A coral reef is built by colonies of tiny marine animals. A hard bottom is an area with low diversity, relatively flat, and characterized by hard materials. Photos A, B, C, and D courtesy of Lad Akins, and photo E courtesy of Babs McDonald.

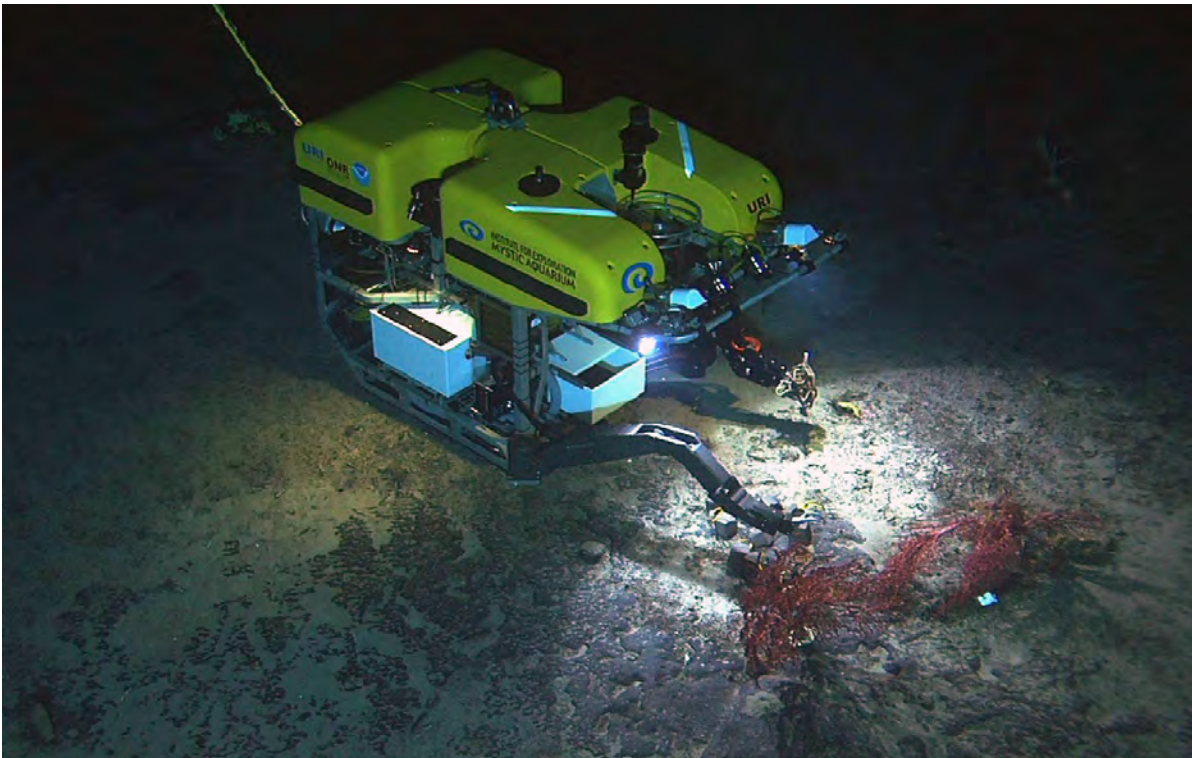


Figure 7. Underwater remotely operated vehicles survey an area by being controlled remotely. Photo courtesy of Mountains of the Sea Research Team, National Oceanic and Atmospheric Administration.



Figure 8. Andy Dehart and Lad Akins tag a lionfish. Photo courtesy of Lad Akins.

Reflection Section



🍁 The scientists wanted to understand how Indo-Pacific lionfish are impacting the Gulf of Mexico ecosystem. To do that, they first needed to ask a different question. What question did the scientists ask in this research? Why did they need to ask this question?

🍁 Describe one challenge of collecting information about the lionfish population in the Gulf of Mexico.

Methods

The scientists identified an area in the Gulf of Mexico where Indo-Pacific lionfish had been sighted. The scientists compared five sources of lionfish **abundance** data collected in this area (**figure 9**). The data collection spanned the time from the first recorded Indo-Pacific

lionfish sightings in this Gulf of Mexico area in 2010 through the year 2012.

The first source of lionfish counts was from an underwater **stationary** camera used by the Southeast Area Monitoring and Assessment Program (SEAMAP). The program uses

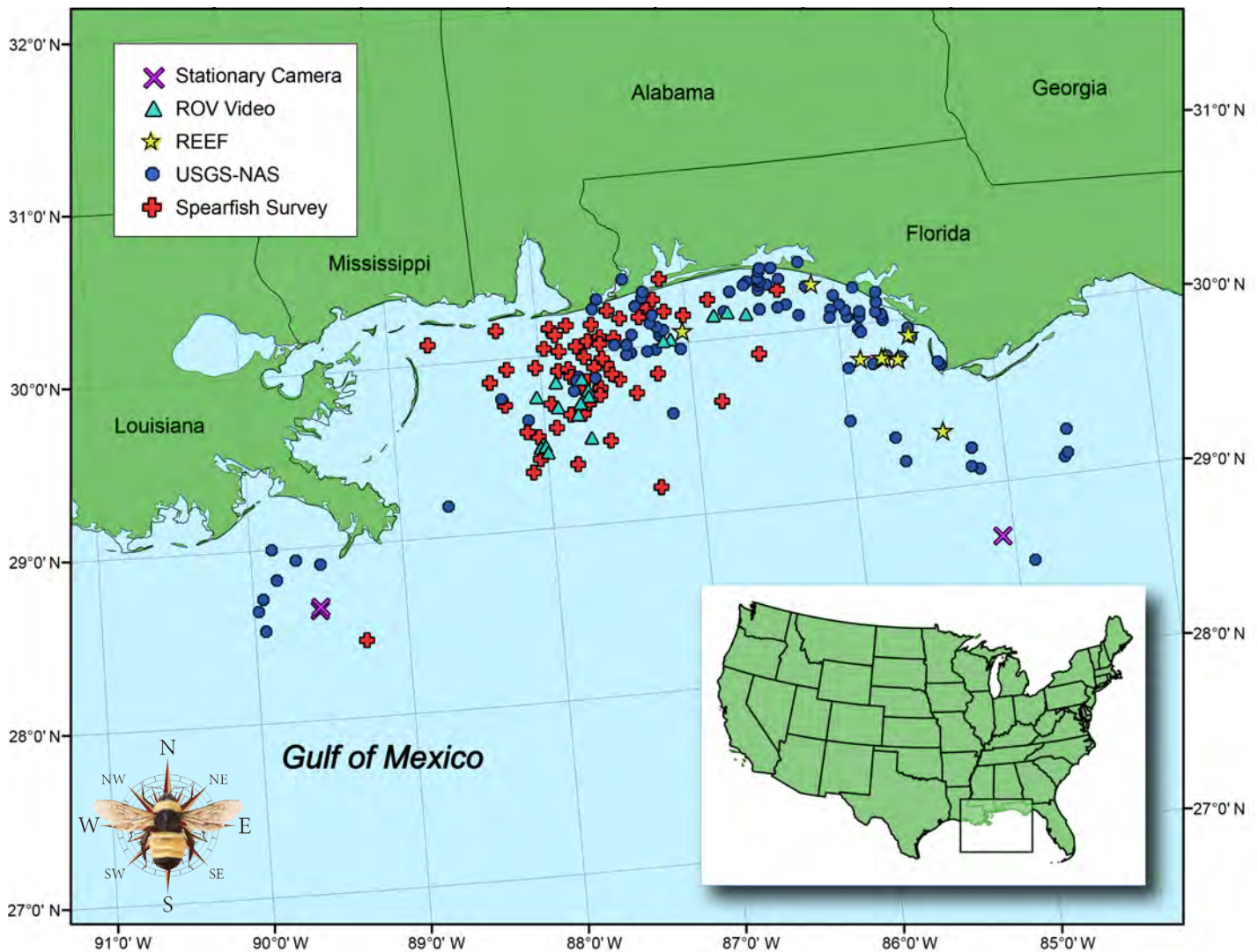


Figure 9. The scientists identified an area in the Gulf of Mexico where Indo-Pacific lionfish had been sighted. Map by Carey Burda and Stephanie Pfeiffer.

underwater photography to identify, count, and understand a range of marine life.

The second source of lionfish counts was from information provided by the Dauphin Island Sea Lab (DISL). DISL uses underwater remotely operated vehicles (ROVs). The ROVs videotape artificial reef structures and the areas around the structures (**figure 10**). A reef is rock, coral, a sandbar, or other structure beneath the water's surface. An artificial reef is a human-built structure meant to provide reef habitat for marine life. Sometimes boats or other materials are purposely sunk to create artificial reefs.

The third source of Indo-Pacific lionfish counts was the U.S. Geological Survey's **Nonindigenous Aquatic Species (USGS-NAS) database**. The USGS-NAS database is like an online library where information is stored. This database enables the U.S. Geological Survey to monitor, record, and analyze sightings of nonnative aquatic species throughout the United States. Citizens, as

What Is the Southeast Area Monitoring and Assessment Program?

The Southeast Area Monitoring and Assessment Program (SEAMAP) collects, manages, and shares information about fisheries in the Southeastern United States. SEAMAP's goal is to provide managers with the best information possible so that the best decisions can be made. SEAMAP is a partnership between Federal and State Governments and universities.

well as scientists, can visit online and report sightings.

The scientists also used data reported into the Reef Environmental Education Foundation (REEF) database. REEF is a



Figure 10. This material is an artificial reef that provides habitat for marine animals. Photo courtesy of Lad Akins.

marine conservation organization. REEF trains recreational SCUBA divers as citizen scientists. These citizen scientist SCUBA divers report sightings of marine fish and other marine organisms.

The last source of information came from an online **questionnaire**. The questionnaire asked 232 licensed Alabama spearfishers to report the number and location of their dives. The questionnaire also asked spearfishers to report any sightings or experiences with lionfish, to provide any photographs they had taken, and to describe their encounters in detail.

What Is a Spearfisher?

A spearfisher is a person who, while swimming below the water's surface, captures fishes using a spear. For many of the spearfishers in this study, the spear is propelled mechanically or shot using the tension of a large rubber band to propel it forward. Spearfishing is not legal in some places.

What Is the Dauphin Island Sea Lab?

The Dauphin Island Sea Lab (DISL) conducts research and provides marine education opportunities to Alabama colleges and universities. Most of DISL's research is about **nearshore** and **estuarine** (es chə rēn) processes in the northern Gulf of Mexico. (See the sidebar on page 38 to learn more about estuaries.)

Reflection Section



- Why did the scientists identify a specific area to study?
- The scientists wanted to compare information from citizen scientists with information collected by marine scientists' ongoing survey efforts. Which of the five data sources were provided by citizen scientists?



Photo courtesy of <http://www.iStockphoto.com>.

Findings

The scientists examined 1,411 photographs and videos recorded by the stationary cameras and the ROV (**table 1**).

Data Source	Pre-2011		2011		2012	
	Attempts	Total Lionfish	Attempts	Total Lionfish	Attempts	Total Lionfish
Stationary Camera	710	0	247	0	189	4
ROV Video	29	0	144	1	92	50
USGS-NAS	Not Applicable	15	Not Applicable	76	Not Applicable	244
REEF	86	0	48	2	57	13
Spearfisher Questionnaire	14,802	230	3,559	1,073	Not Applicable	Not Applicable

Table 1. Yearly number of attempts to observe Indo-Pacific lionfish and numbers of lionfish sighted for each data source. Notice the numbers of total lionfish counted in each year.

The USGS-NAS database first recorded lionfish sightings in the Gulf of Mexico in 2010. However, lionfish were seen off the southeast coast of Florida as early as 1985. Reports indicated that most sightings were of 1 to 4 lionfish, although some reports showed up to 50 lionfish per sighting. Lionfish were observed between 2 meters in depth in shallow seagrass meadow habitats and up to 40 meters in depth in offshore and artificial reef habitats. The REEF database did not have any lionfish sightings in the Gulf of Mexico before 2011.

Fifty-seven licensed spearfishers answered the questionnaire. These 57 spearfishers had

participated in more than 14,000 dives. These SCUBA divers had an average of 13 years of experience and an average of 17 dives every year in the northern Gulf of Mexico. One-third of the spearfishers reported seeing lionfish during a dive. In total, spearfishers saw 1,303 individual lionfish. Of these, 82 percent were observed in 2011.

Although some of the lionfish sightings were spread out across the study area, most of the sightings occurred within the same area (see figure 9 on page 47).

Number Crunches

- How many individual lionfish were observed by spearfishers in 2011?
- What was the average number of dives per spearfisher?



Citizen Science Connections

iCoast is a project aimed at improving scientific knowledge of coastal erosion issues. Coastal erosion is the process or state of washing away land in coastal areas. Coastal erosion is a common issue following extreme storm events, such as hurricanes. Extreme storms can change or damage the natural environment and human-made structures.

Scientists have taken more than 140,000 photos of coastal areas before and after 24 different extreme storms. However, the scientists are unable to compare and contrast all the photos by themselves. Scientists are asking citizen scientists to use iCoast to identify changes and damage to coastal areas using the photos.

iCoast lets citizen scientists:

- Learn about coastal erosion issues;
- Compare and contrast coastal erosion photos;
- Submit data about coastal erosion following extreme storm events;
- Contribute to science.

iCoast is a project created by the U.S. Geological Survey. More than 1,000 citizen scientists assist scientists with the iCoast project. To learn more, visit <http://coastal.er.usgs.gov/icoast/about.php>.



Reflection Section

- Observe table 1. What is the general trend in lionfish sightings shown by this table?
- Which source of lionfish sightings provided the most information? Why do you think this source might have provided the most information?
- Observe figure 9 on page 47. What patterns do you observe in the sighting locations by the source of the sighting?
- What does the map on page 47 tell you about lionfish location in the study area?



Discussion

The scientists noted that spearfishers, SCUBA divers, and other citizen-based sources of lionfish counting were effective at documenting the rapid movement of lionfish into the study area. Therefore, citizens could play an important role in providing an early warning of other **nonnative** species as they move into new ecosystems.

All of the sources of lionfish counting examined by the scientists showed a similar pattern. Most sources showed lionfish moving into the study area in 2010 and their numbers increasing every year through 2012. The USGS-NAS database relies on volunteers and does not include a measure of effort. The scientists do not know how many times volunteers tried to observe lionfish as compared with the numbers they reported. This lack of information limited the usefulness of the USGS-NAS database.

The survey of spearfishers enabled the scientists to compare effort with lionfish

abundance. From this survey of spearfishers, the scientists learned that information provided by a small group of people can provide important additional information about lionfish abundance.

The scientists noted that this particular project is just one example of how citizen scientists can assist scientists with understanding ecosystem changes. In this case, the scientists were better able to understand the rate and locations of nonnative fishes' movement into a new ecosystem. Understanding other events, such as the impact of oil spills or hurricane damage, may also benefit from the involvement of citizen scientists. The popularity and improvement of mobile applications (apps) will provide even more ways for citizen scientists to report their observations. With improved mobile technologies, citizen scientists may become even more effective as contributors to science.

Reflection Section



The scientists said that citizen scientists could be an early warning system for the movement of other nonnative species into new ecosystems. Name at least two other situations in which citizen scientists might provide information before scientists could collect it.



How might the popularity and improvement of mobile apps enable citizen scientists to be more effective at contributing to scientific knowledge?



Adapted from Scyphers, S.B.; Powers, S.P.; Akins, J.L.; Drymon, J.M.; Martin, C.W.; Schobernd, Z.H.; Schofield, P.J.; Shipp, R.L.; Switzer, T.S. 2015. Rapid expansion of an invasive species documented through a social-ecological network. *Conservation Letters*. 8(4): 242-250. DOI: 10.1111/conl.12127, http://www.reef.org/reef_files/2014_Scyphers_etal_ConLetters_Lionfish.pdf

Glossary

abundance (ə bən dən(t)s): Degree of plentifulness.

aquatic (ə kwä tik): Growing or living in or upon water.

conserve (kən sərv): To avoid wasteful or destructive use of something.

database (dā tə bās): A comprehensive collection of related data organized for convenient access, generally in a computer.

endangered (in dān jərd): Being in danger or peril.

invertebrate (in vər tə brət): An animal lacking a backbone (spinal column). About 95 percent of all animals are invertebrates. These include all animals except mammals, birds, reptiles, amphibians, and fish.

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

nearshore (nir shör): The nearshore region includes water from a lake, bay, or ocean shoreline to 30 meters in depth.

nonindigenous (nän in dij ə nəs): Growing, living, or occurring in a region or environment which is not native to the organism or thing.

nonnative (nän nā tiv): Not naturally occurring in an area.

predator (pre də tər): An animal that lives by killing and eating other animals.

questionnaire (kwes chə ner): Printed or written form of questions used to gather information.

stationary (stā shə ner ē): (1) Not moving; (2) staying in one place or position.

unique (yu nēk): (1) Being the only one; (2) Unusual.

venomous (ve nə mäs): Capable of putting venom into another animal's body usually by biting or stinging it.

Accented syllables are in **bold**. Marks and definitions are from <http://www.merriam-webster.com>. Definitions are limited to the word's meaning in the article.



Time Needed

- 20 minutes to organize
- Up to 2 days to collect data
- 30-40 minutes to discuss FACTivity exercise



Materials

- 2 cameras per group (phone cameras, tablet cameras, or point and shoot cameras)

The question you will answer in this FACTivity is: How does the information you collect vary when you use different ways to collect the same information?

Methods

Divide your class into groups of four students each. Make sure each group has access to two cameras, such as those listed in the “Materials” section. For this FACTivity, your group is curious about the popularity of different types of shoes. Your group would like to conduct a research project to determine the abundance of a certain type of shoe in your school.

First, your group will decide what type of shoe you are interested in counting. You could select, for example, a particular brand, a particular type of shoe, a particular shoe color, or any combination.

Each member of your group will be responsible for collecting data about the abundance of this shoe in your school. When you count, you will count a pair of shoes as one.

Two group members will conduct their own observational survey. Each member will count the number of pairs of the particular shoes he or she observes in school over 2 days.

Another group member will identify a busy location, such as the building or cafeteria entrance. This group member will take a photo of all the passing shoes every 5 seconds for 2 minutes during a time when many students are passing. For example, the time could be at the start or close of school, or at the lunch hour. The camera should be pointed at the same location for every photograph. Use a tripod if possible.

One group member will take 24 photos of students’ shoes during a busy time, such as during lunch or as students are getting ready for their day. This student can move freely and can photograph any shoes she or he wants to photograph. If a pair of the selected shoes is seen, it should be photographed.

All group members will record their counts in the graphic organizer on page 55.

Lion in Wait **FACTivity** Graphic Organizer

Group members: _____

Shoe Description		
Group Member Data Collection Method	Date and Time	Number of Shoes Counted
Survey #1		
Survey #2		
Stationary Camera		
Roving Camera		

After all data have been collected, your teacher will hold a class discussion based on the following questions:

1. How did the number of chosen shoes counted vary by data collection method?
2. What are the similarities between the data collection methods?
3. What are the differences between the data collection methods?
4. What are the advantages of each data collection method?
5. What are the disadvantages of each data collection method?
6. How does each data collection method compare with each similar source of lionfish abundance data in this article? (See Graphic Organizer to Compare Methods on page 56.)
7. Which of the group's members are most like the citizen scientists in this article?

Lion in Wait FACTivity Graphic Organizer to Compare Methods

	Use the space below to compare the methods.
<p>ROV Video (Lion In Wait)</p> <p>vs.</p> <p>Roving Camera (FACTivity)</p>	
<p>Stationary Camera (Lion In Wait)</p> <p>vs.</p> <p>Stationary Camera (FACTivity)</p>	
<p>Questionnaire (Lion In Wait)</p> <p>vs.</p> <p>Surveys (FACTivity)</p>	

If you are a trained Project Learning Tree educator, you may use “Did You Notice?” and “Improve Your Place” as additional resources.



Web Resources

U.S. Geological Survey-NAS Animated Map of Lionfish Spread

<https://nas.er.usgs.gov/queries/SpeciesAnimatedMap.aspx?speciesID=963>

U.S. Geological Survey-NAS Point Map of Lionfish Sightings

<https://nas.er.usgs.gov/viewer/omap.aspx?SpeciesID=963>

Dauphin Island Sea Lab

<http://www.disl.org>

Southeast Area Monitoring and Assessment Program

https://sero.nmfs.noaa.gov/operations_management_information_services/state_federal_liaison_branch/seamap/index.html

U.S. Geological Survey Nonindigenous Aquatic Species Program

<https://nas.er.usgs.gov/>

Reef Environmental Education Foundation

<https://www.reef.org/>

Reef Environmental Education Foundation Lionfish Page

<https://www.reef.org/lionfish>

Reef Environmental Education Foundation Free iPhone Mobile App for Lionfish Sightings:

Search for “REEF Lionfish Sightings”

Marine Advanced Technology Education Center (teaching resources for marine technology, including ROVs)

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



Invasion of the Song Snatcher!

The Influence of Spotted Knapweed on Chipping Sparrow Song Diversity



Photo courtesy of <http://www.istockphoto.com>.

Meet the Scientists

► **Ms. Yvette Ortega, Ecologist:** I love searching for birds' nests. It is like a treasure hunt, only you follow the birds around in search of clues. For example, a bird on the way to its nest might have "whiskers." "Whiskers" could be any type of nest construction material such as grass gathered in the beak. A bird with whiskers will lead you right to its nest if you stand back and let it do its thing.



Photo courtesy of Yvette Ortega.

► **Ms. Aubree Benson, Fisheries Biologist:** In the attached photo, I am holding a large (7 pound) bull trout. We captured this trout below the Emily-A-Dam, which is in the background. The dam was on the Clearwater River near Seeley Lake, Montana. I had just finished implanting a radio transmitter in this fish, which I then carried over the dam and released. Then I tracked the trout's movement to its spawning **tributary**. The fish was unharmed from the process. This experience was a part of my research as a Master's student at the University of Montana.



Photo courtesy of Aubree Benson.

During this research, I helped determine that the dam had a major impact on the bull trout population. After that, Montana Fish, Wildlife, and Parks removed the dam in 2010 to benefit bull trout.

One of my favorite science-related experiences was related to the bull trout research. To identify individual trout, we clipped the adipose fin (the little fin just before the tail fin) of each bull trout we moved over the dam. Once the fish swam to their spawning stream, we **snorkeled** to determine how many fish in the spawning tributary were fish that had a fin clip versus fish that had migrated from elsewhere. We were able to show that over 40 percent of the spawning population was made up of fish we had passed over the dam. Those data helped us justify why the dam needed to be removed!

Meet the Scientists

► **Dr. Erick Greene, Wildlife Biologist:** My favorite science experiences have always been in the field observing fascinating things in nature. These experiences are what give me ideas about interesting things that might be going on, and these observations can lead to a scientific research project.

A couple of experiences stand out for me. I spent a lot of time in the high Canadian Arctic about 800 miles north of the Arctic Circle. I once got to watch a mother polar bear teaching her two cubs how to hunt seals out on the sea ice. She communicated to them, and they crouched down and remained immobile on the ice. The cubs watched her as she spent an hour slowly stalking forward on the ice. She would only move forward when the seal put its head down and was not looking around.

Another powerful experience was spending a lot of time in the Okavango Delta in Botswana. I was on a research project studying how olive baboons communicate with each other about predators. As I spent time with the troop of 80 baboons, it was fascinating to see that they all know each other (by sight and also by their voices). They communicate with each other about predators with a complex set of alarm calls. The baboons can warn each other about lions, snakes, leopards, and other dangers.



Photo courtesy of Erick Greene.

What Kinds of Scientists Did This Research?

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

fisheries biologist: This scientist studies fish living in the wild, including what they eat, their habitat, and how they interact with their environment.

wildlife biologist: This scientist studies animals living in the wild, including what they eat, their habitat, and how they interact with their environment.

Glossary words are **bold** and are defined on page 69.

Thinking About Science



Scientists often find a particular topic that interests them and study this topic in depth. As scientists study one topic more closely, they come up with more detailed and specific questions for which they would like to know the answers. Sometimes their discoveries about one topic help inform scientists about another related topic.

In this study, the scientists were interested in learning more about how an invasive plant species was affecting a particular bird species and the songs of those birds. The scientists thought this specific information gathered from this research could help them understand the particular bird and invasive plant. The scientists also thought that this research could help them understand the response of other songbird populations to changes in their habitat quality.

Thinking About the Environment



Invasive species are any plants, animals, or organisms that are not **native** to the ecosystem they are in and are likely to cause harm to the environment, the economy, or human health. In this study, scientists were concerned with an invasive plant called spotted knapweed (**figure 1**).

Spotted knapweed was accidentally brought to the United States from Eastern Europe in the late 1800s. The spotted knapweed seeds were mixed in with alfalfa and clover seeds. Spotted knapweed can invade a wide variety of habitats from open areas like grasslands to those with more dense vegetation like forests



Figure 1. Spotted knapweed has purple flowers when in bloom. Photo courtesy of John Cardina, Utah State University, and <http://www.bugwood.org>.

(**figure 2**). The roots of spotted knapweed give off a chemical that stops the growth of other plants. Spotted knapweed also is a strong competitor for resources such as water and space and **displaces** the native plants in this way.

When spotted knapweed spreads, native plants can no longer grow in that area and the plant diversity is greatly reduced. Many animals depend on a diversity of plants for food and habitat. Spotted knapweed is a poor substitute for the habitat and food needs of these animals. The invasion of spotted knapweed, therefore, negatively impacts the food and habitat options for these animals.



Figure 2. Spotted knapweed often invades roadside areas. Photo courtesy of Steve Dewey, Utah State University, and <http://www.bugwood.org>.

Introduction

Invasive species such as spotted knapweed can have an effect on a habitat and animals in that habitat (Read “Thinking About the Environment” for more information). In this study, the scientists wanted to determine how spotted knapweed affects **migratory** songbirds and their songs. In particular, the scientists studied chipping sparrows (**figure 3**). Chipping sparrows migrate to different areas for reproduction. These areas are called breeding grounds.

In migratory songbirds, it is common for the **yearling** male bird to adopt the song of the birds that are already in the breeding area. Chipping sparrows tend to match the songs of the older chipping sparrows at the site to which they have migrated. The yearlings typically imitate the song of the older birds because the older birds arrived on the breeding grounds first and already have a clear song (**figures 4 and 5**).



Figure 3. Chipping sparrows can be found around trees, although they spend a lot of time **foraging** on the ground. Chipping sparrows mainly eat the seeds of a variety of grasses and herbs. During the breeding season, songbirds such as the chipping sparrow add insects to their diet to give them an extra boost of energy for reproduction. Photo courtesy of Aubree Benson.



Citizen Science Connections

Do invasive species live in your schoolyard or backyard? Help scientists track the spread of invasive species across the United States! Citizen scientists can use the Early Detection & Distribution Mapping System (EDDMapS). Visit <http://www.eddmaps.org/> and BugwoodApps to learn more and contribute to this research.

EDDMapS lets citizen scientists:

- Learn about invasive species;
- Report invasive species observations;
- Review maps of invasive species.

EDDMapS
Early Detection & Distribution Mapping System

EDDMapS is a project launched by the University of Georgia. It now has a **database** of more than 2.5 million invasive species sightings made by both scientists and citizen scientists.

The scientists wanted to know if the chipping sparrows still had a similar song adoption process in areas heavily invaded by spotted knapweed. The scientists hypothesized that the number of older birds would decrease in heavily invaded spotted knapweed areas, compared with the number of yearling birds.

Further, the scientists hypothesized that this decrease in the number of old compared to yearling birds would lead to increased song similarity among birds in the area. They

believed there would be fewer song options for yearling birds to imitate.

Increased song similarity may cause the habitat to be less suitable for chipping sparrows. One reason the habitat may decline in suitability is that female birds may avoid the habitat because of lack of song variety from males. Song variety from male birds can indicate the health of the male and may indicate the success of offspring from that bird.



Figure 4. Chipping sparrows lay beautiful light blue eggs with dark speckles. Photo courtesy of Aubree Benson.



Figure 5. Recently hatched chipping sparrow waiting for food. Photo courtesy of Aubree Benson.

The scientists collected data on chipping sparrow songs, gender, and numbers to determine whether their hypotheses were correct. The scientists wanted to compare this information in areas that were invaded with knapweed and areas that had native vegetation.

Reflection Section



- What did the scientists want to study?
- Why is a bird's song important?

What's In a Song?

As humans, we can talk, write, and sing to communicate with others. Birds cannot talk or write. Birds rely mostly on singing and bird calls to communicate with other birds.

Some birds can only learn one song. Other birds can learn over 200 songs, such as the northern mockingbird.

Most singing birds that you hear are male birds. Like the songs that we listen to on our electronic devices, each song has a message. The male birds sing to send a message to females or other males in the area. Singing can attract females. It can also help warn other male birds to avoid the singing bird's territory. Bird songs are often loudest in the morning, but scientists are not sure why. Why do you think that bird songs are loudest in the morning?

For additional information on bird songs, visit <http://biology.allaboutbirds.org/birdsong/>.



Northern mockingbirds imitate the songs of other birds, other animals, and even car alarms. Photo by Budd Titlow of Naturegraphs.

Methods

The scientists studied six plots in the Lolo National Forest in western Montana (**figure 6**). Three of the plots had native vegetation and three of the plots were heavily invaded by spotted knapweed (**figures 7a and 7b**). The scientists collected data in 2005 and 2006.

The scientists lured chipping sparrows into mist nets by playing bird songs and calls that had been recorded in the area (**figure 8**). Each bird was marked with a unique combination of one aluminum band and three color bands (**figure 9**).

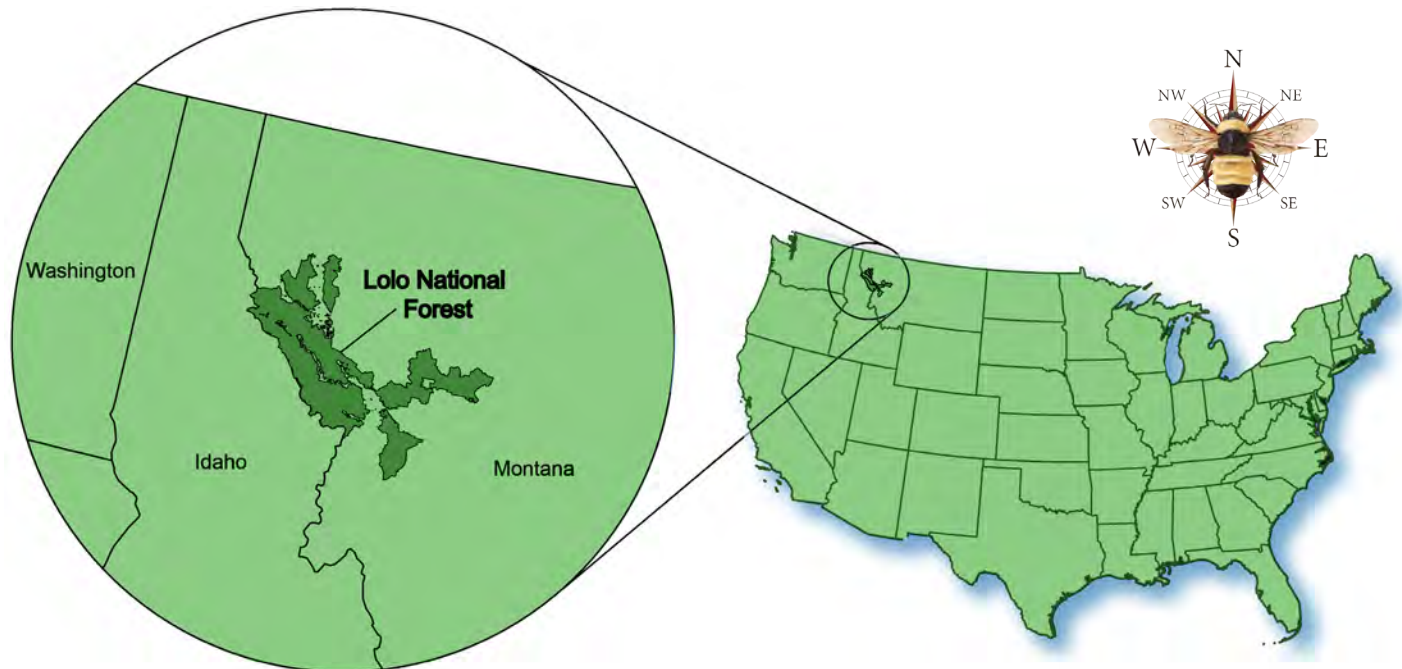


Figure 6. Lolo National Forest is located in western Montana and consists of 2 million acres. Map by Carey Burda and Stephanie Pfeiffer.



Figure 7a. A plot with native vegetation. Photo courtesy of Yvette Ortega.



Figure 7b. A plot invaded by spotted knapweed. Photo courtesy of Yvette Ortega.

The scientists used information about **molting** and **plumage** characteristics to determine whether the bird was a yearling or an older bird. Yearling birds spend part of their early life with a different plumage than older birds. As young birds move through their life cycle, molting occurs and yearling plumage is replaced with adult plumage. Observers conducted searches twice a week for banded birds on the study plots. The scientists recorded the information from these searches (**figure 10**).

The scientists also recorded the bird songs during the breeding season each year (**figure 11**). Only one of the scientists measured and made notes about all of the bird songs. The scientists then took the data they gathered and used computer software to help them analyze the information.



Figure 8. Mist nets help scientists capture and release birds without harming them. These scientists are removing a bird from a mist net so they can study the bird. Photo courtesy of Mariko Yamasaki.



Figure 9. Notice the tiny bands on the bird's leg. The bands do not hurt the bird and help the scientists keep track of the different birds. Photo courtesy of Aubree Benson.



Figure 10. The scientists inspected the birds and made notes and observations about them. Photo courtesy of Aubree Benson.



Figure 11. Aubree Benson recorded the songs of the chipping sparrows. Photo courtesy of Jennifer Steffan.

Reflection Section



- ❖ Scientists use different methods to collect data about a topic. Describe one method used by the scientists in this study.
- ❖ Why do you think it is a good idea to have the same scientist measure and make notes about all the bird songs? (Hint: Think about a time when you and a friend did the same activity, but later when you talked about the activity, you both remembered different things about the event. Why might this cause a problem in the world of science?)



Citizen Science Connections

Birds are an important part of every ecosystem. The presence or quantity of birds in a location can tell scientists a lot about the health of birds and the environment. Using eBird (<http://www.ebird.org>), scientists are asking citizen scientists to collect data about where and when they see birds. The study of birds is called ornithology (or nə *thä* lə jē).

eBird lets citizen scientists:

- Record the birds they see;
- Keep track of their bird lists;
- Explore maps;
- Share their sightings;
- Contribute to science.

eBird

eBird is a project created by the Cornell Lab of Ornithology. The eBird database collects millions of citizen scientist bird sightings each month for use by scientists, land managers, and other citizen scientists. Join the effort today!

Findings

The scientists found that fewer birds returned to the sites invaded by spotted knapweed (**figure 12**). For birds, returning to a given site year after year is closely linked to breeding success.

Overall, the scientists recorded more than 96 percent of the males' songs. Of those birds, none of them changed their song between

years. The scientists also found that song similarity among individuals was higher for yearling birds than older birds.

Song similarity among male birds was higher in the areas invaded by spotted knapweed. The diversity of song types was lower in spotted knapweed areas (**figure 13**).

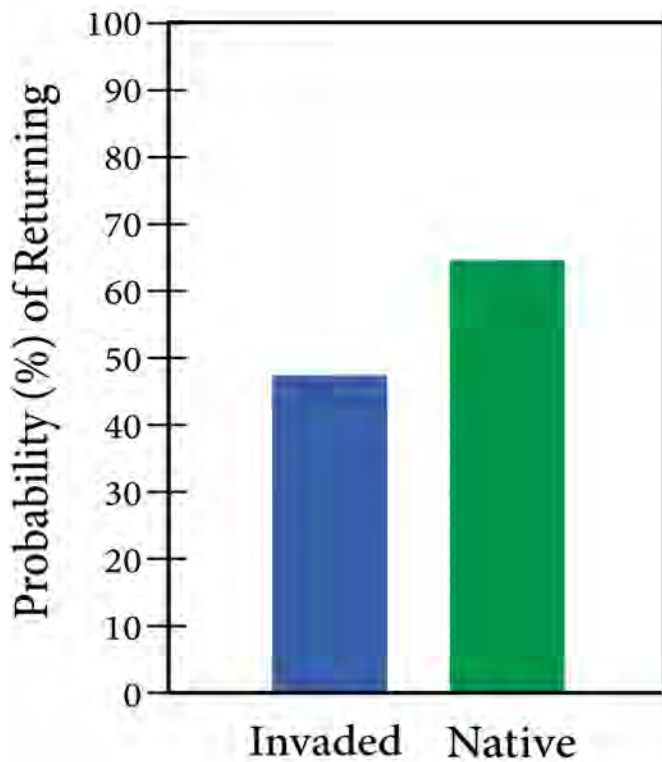


Figure 12. The scientists found that fewer birds returned to invaded areas as compared to returning to areas with native plants. Graph by Stephanie Pfeiffer.

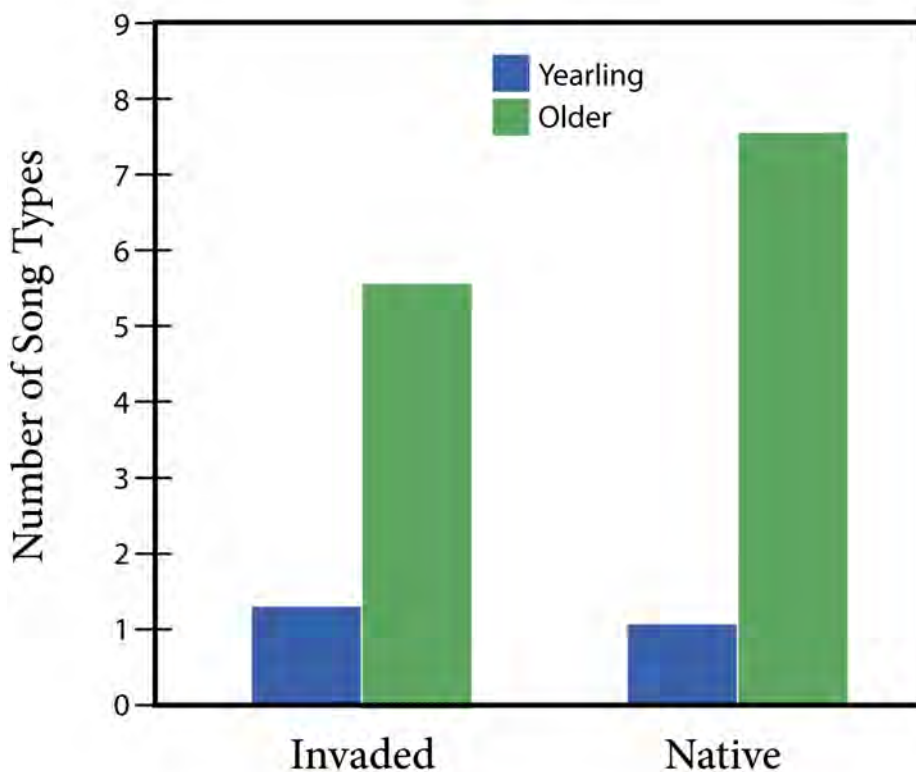




Figure 13. The number of song types was also lower in invaded compared to invaded areas. Graph by Stephanie Pfeiffer.

Reflection Section

-  In your own words, summarize what the scientists found.
-  Review figure 13. What is one difference you notice for the older birds when you compare them in the native versus the invaded habitat?



Discussion

The scientists' findings supported their **hypothesis** that invasion of spotted knapweed has a negative effect on chipping sparrow populations. An invasion of spotted knapweed reduces the quality of the bird breeding area in multiple ways. The presence of spotted knapweed decreases the food resources available to the birds. Once spotted knapweed has taken over a breeding area, birds are less likely to return from year to year. Yearling birds tend to take the place of the birds that have left the invaded area.

With fewer older birds around, the chipping sparrows have fewer songs to imitate. Therefore, song similarity at the spotted knapweed sites increases leading to a reduction in the number of song types sung. The increase in song similarity may **deter** female birds from this site. They may be deterred because fewer mating choices are available to them compared to the native-plant breeding sites. Overall, the scientists believe that bird songs may serve as an important indicator of habitat quality and population status for a variety of migratory songbirds.

Reflection Section

- ✿ Explain one reason why spotted knapweed may impact the chipping sparrow.
- ✿ Do you think that other migratory songbirds may respond similarly to invasive plant species invasions? Why or why not?



Glossary

database (dā tə bās): A comprehensive collection of related data organized for convenient access, generally in a computer.

deter (di tər): To cause someone, to decide not to do something.

displace (di splās): To force (people or animals) to leave the area where they live.

forage (fōr ij): The act of taking food by animals, usually taken by browsing or grazing.

habitat (ha bə tat): The environment where a plant or animal naturally lives and grows.

implant (im plant): To place something in the body of a living thing, in this case, a fish by means of surgery.

migratory (mī grə tōr ē): Having a characteristic of moving from one place to another on a periodic basis.

molt (mōlt): To shed hair, feathers, outer skin, shell, or horns with the cast-off parts being replaced by a new growth.

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

plumage (plü mij): The feathers of a bird.

snorkel (snōr kəl): To use a tube when swimming so that the swimmer can breathe with his or her head under water.

spawn (spōn): To produce or lay eggs in water.

tributary (trib yə ter ē): A stream flowing into a larger stream or a lake.

yearling (yi(ə)r līŋ): An animal, that is a year old or in the second year after birth.

Accented syllables are in **bold**. Marks and definitions are from <http://www.merriam-webster.com>. Definitions are limited to the word's meaning in the article.



Time Needed

One class period

Materials

(for each student or group of students)

- Bird observation tally sheet
- Pencils
- Clip boards
- Binoculars (optional)
- Field guide (optional)

The question you will answer in this FACTivity is: How many birds do I notice in my schoolyard habitat?

Methods

First, break into small groups and brainstorm a list of reasons why you feel birds are important. Title the list "Why Are Birds Important?" After your groups brainstorm at least three reasons that birds are important, come together as a whole class and create a classroom list. Hold a brief discussion of why birds are important.

Next, have everyone in your class think about the habitat in your schoolyard. Imagine spending 10 minutes outside walking around in the schoolyard habitat. Write down an estimate for how many different individual birds you think you will see and hear.

Your teacher will collect your estimates and write them on the board. Did the groups report a wide variety of estimates? Add all the class estimates together and calculate an average for the estimate.

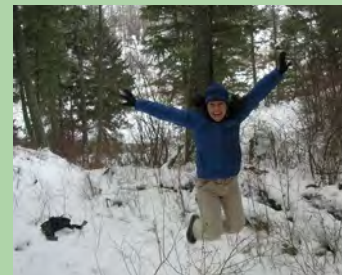
As a class, go outside and walk through the schoolyard habitat for 10 minutes. Your teacher will set a timer. Remember to be quiet and observe with your eyes and ears. Make tally marks on your bird observation sheet (page 71) when you see or hear

A Note From the "Invasion of the Song Snatcher" Scientist

In an activity like this one, birds are often more easily heard than seen. Particularly during the birds' breeding season, if you listen carefully, you are likely to notice many more birds with your ears than if you are only using your eyes.

Have Fun!

Ms. Yvette Ortega



an individual bird. Then tally only those birds that you see and hear. Everyone in the class may see or hear different birds. Count each individual bird only once.

After your observation time outside, add the tally marks in each column. Create a class total for the first two columns and find the average for these columns.

- How does the class average from your time outside compare to your class's individual and average estimates about the number of birds that were in the schoolyard habitat?
- What do you notice about the number of birds you heard versus the number of birds you saw?
- How are you surprised by your results?

Have a class discussion about the number of birds you observed. What are some reasons why there may be so few or so many birds? Name three ways your class can help create a better schoolyard habitat for birds.

Invasion of the Song Snatcher Bird Observation Tally Sheet

Name _____ Date _____

See a Bird	Hear a Bird	Notes About What You Hear or See

FACTivity Extension



The *Natural Inquirer* website has a “Birding in the Classroom” Outdoor FACTivity which provides many more birding activities. This Outdoor FACTivity was adapted from Cornell University’s BirdSleuth program. To see the full lesson plan, visit [http://www.naturalinquirer.org/UserFiles/File/Birding%20FACTivity\(1\).pdf](http://www.naturalinquirer.org/UserFiles/File/Birding%20FACTivity(1).pdf).

Technology Extension



Time Needed

One class period

Materials

(for each student or group of students)

- An original song that is age and content appropriate for students
- One or more covers of the original song (Note: A cover is a new performance or recording of a previously recorded song. The cover is recorded or performed by someone other than the original performer.)
- A way to play chosen songs for the class to hear
- Access to the Internet and a way to listen to .wav files
- Bird song files (.wav files) located at <http://www.naturalinquirer.org>
- Spectrograms (on page 74)
- Graphic organizer

The questions you will answer in this FACTivity are: What similarities and differences do you notice between bird songs? How does the way a song sounds have an effect on you?

Methods

To start thinking about songs and sounds, your teacher will play a song for you. First, your teacher will play the original song. Then your teacher will play the same song, but with someone else singing it. (Note: Some songs may have several different versions that your teacher can play.) Which song did you like better? Why? Have a class discussion about this introduction activity and how it is similar to what happens to the birds in the “Invasion of the Song Snatcher” article you read.

Next, you will listen to six recorded chipping sparrow bird songs that the scientists

in this study recorded. First, simply listen to each file. Next, play each file several times in a row.

As you listen to each song, take some notes about the song on the graphic organizer on page 73. For example, you may want to think about the following questions:

- What do the notes sound like to you?
- Is the song fast or slow?
- Does the sound remind you of anything?

Make a note of the song or songs that seemed to have the most differences.

Invasion of the Song Snatcher Bird Song Graphic Organizer

Name _____ Date _____

Bird Song	Notes About What You Hear in the Song
Song 1	
Song 2	
Song 3	
Song 4	
Song 5	
Song 6	

Now, examine the spectrogram illustrations provided by the scientists in figure 15. A spectrogram is a visual representation of sound qualities such as pitch and how this changes over time. In the spectrograms, the black shapes are the notes, repeated by the bird. The vertical axis (y-axis) shows the pitch of the note. For example, this axis shows whether the notes are high or low or represent a range. The horizontal axis (x-axis) shows the change over time. The horizontal axis is time, with all of the spectrograms depicting 0.5 seconds.

After you have listened to the bird songs and reviewed the spectrograms, answer the following questions:

- Do the spectrograms help to show what you heard?
- What is one thing that you learned today about birds?
- What are you still curious about?

To learn more about bird songs and calls, visit <https://www.allaboutbirds.org/how-to-learn-bird-songs-and-calls/>.

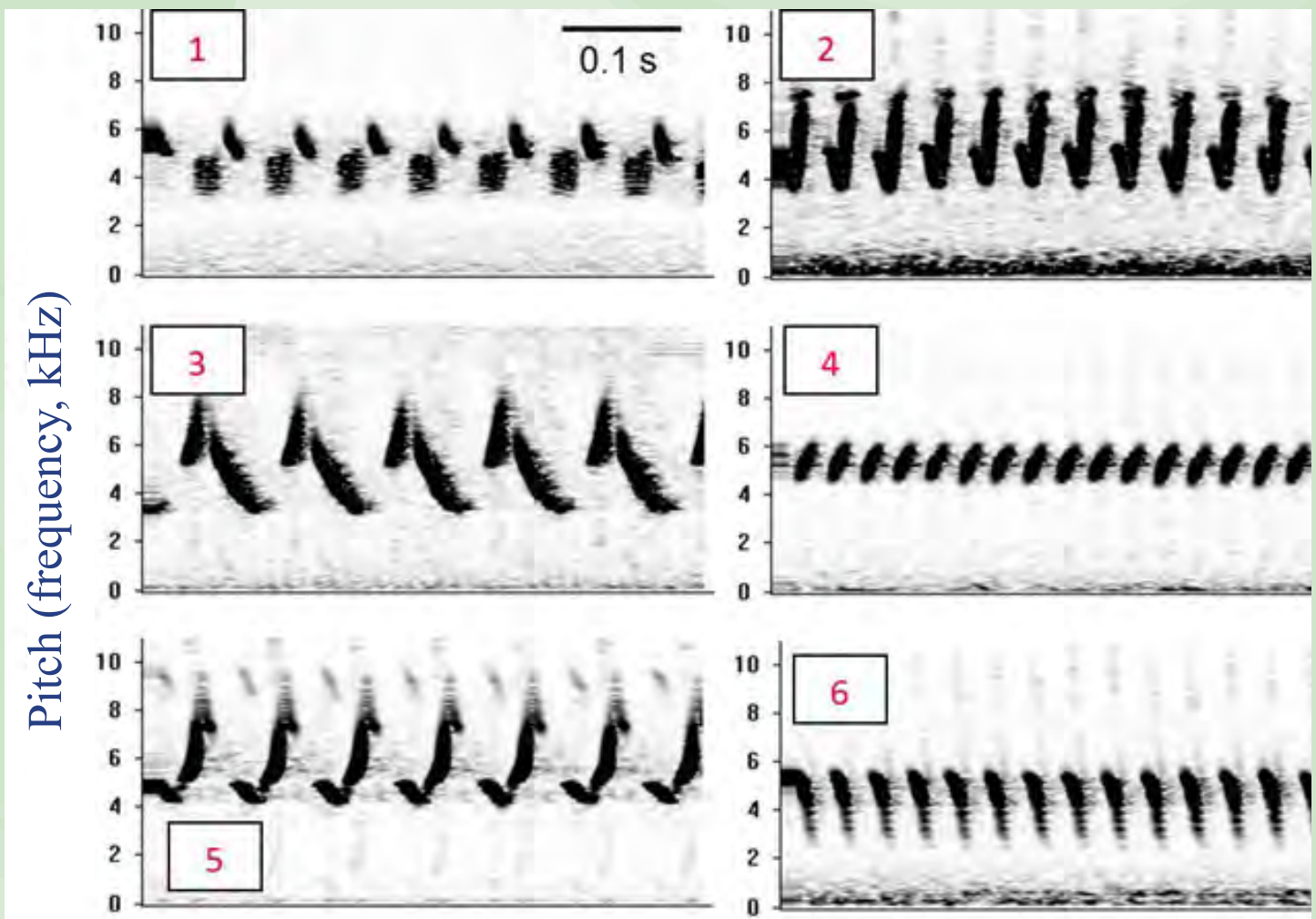


Figure 15. Spectrograms of chipping sparrow songs (0.5 second clips) illustrating differing song types identified. Each spectrogram shows one unique song type. The number in the box shows what song number the spectrogram represents. Photo courtesy of Yvette Ortega.

If you are a trained Project Learning Tree educator, you may use “Have Seeds Will Travel” as an additional resource.



Natural Inquirer Connections

You may want to refer to this *Natural Inquirer* article for additional information and FACTivities related to this article:

- “Goll-ly! Don’t Take a Knapweed!” in the Invasive Species edition of *Natural Inquirer*.

This article, along with others, can be found at <http://www.naturalinquirer.org/all-issues.html>.



Web Resources

Cornell Lab of Ornithology – Chipping Sparrow

https://www.allaboutbirds.org/guide/Chipping_Sparrow/id

(Note: To find the eBird data on the chipping sparrow, go to the website provided above. On the right hand side of the page under the “Range Map,” click on “View dynamic map of eBird sightings.”)

Lolo National Forest

<https://www.fs.usda.gov/lolo/>

Spotted Knapweed – USDA Forest Service Weed of the Week

https://www.na.fs.fed.us/fhp/invasive_plants/weeds/spotted-knapweed.pdf



Nature's Notebook: Taking the Pulse of Our Planet



Observation is watching carefully and making note of details. Whether you are outside or inside the classroom, you make observations every day. Maybe you saw the first snowflakes of winter on your way to school or maybe you saw a bird feeding its recently hatched chicks. Observation is one way scientists create questions and conduct research. Just as scientists make observations, you can help make observations as a citizen scientist (**figure 1**).

Citizen scientists contribute to hundreds of different projects. One topic that uses citizen scientist observations is climate change.

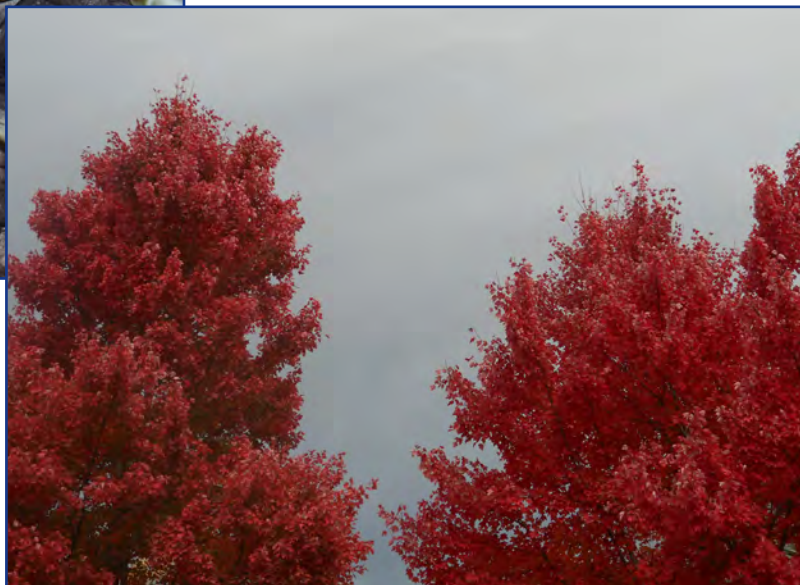
Climate change is a change in global or regional climate patterns. Changes in climate patterns can affect plants and animals in different ways. Phenology is the periodic series of life events in plants and animals that are related to climate.

Phenology is expressed in many different ways. Plants use climate cues to begin flowering or changing color each year. Many birds begin to migrate to their breeding grounds based on the length of day. Amphibians, such as frogs and salamanders, depend on air temperature and precipitation to start breeding each year. These plant and animal phenology events match patterns in climate (**figure 2**).



Figure 1. Kids and adults who are citizen scientists can use *Nature's Notebook* to report what they have seen in nature. Photo courtesy of Michelle Andrews.

Figure 2. Each plant has its own phenology. Many trees change color each fall when the days reach a certain length. Climate can affect how long and how bright leaf color gets in the fall. Photo courtesy of Babs McDonald.



Changes in plant or animal phenology can show larger changes to Earth and its environment. Just like a change in our heartbeat could show problems in our health, changes in phenology could show signs of a problem in our environment. Some plants and animals may be able to adapt to changes in climate. However, scientists are concerned that some plant and animal phenology may be disrupted by climate change.

The climate can change across all of Earth's ecosystems. Scientists, therefore, are not able to make all of the scientific observations they need by themselves. Some scientists rely on technology located around the world—such as weather stations—to record data (**figure 3**).

Other scientists ask citizen scientists to help gather the data according to a protocol. A protocol is a stated procedure and guarantees that each citizen scientist collects data in the same way. A protocol makes results more



Figure 3. Scientists studying climate change need to track worldwide climate information. To help gather data, some scientists rely on weather stations around the world to keep track of air temperature, precipitation, and other indicators. This weather station is located at the University of Georgia in Athens, Georgia. Photo courtesy of Jean Szymanski.

reliable for scientists. Without the help from people across the world, some scientists would be unable to collect all the data they need to complete their research. This lack of needed information would make climate change difficult to study.

Once the data are collected by a protocol, they are often entered into a **database**. A database makes it easier for scientists to

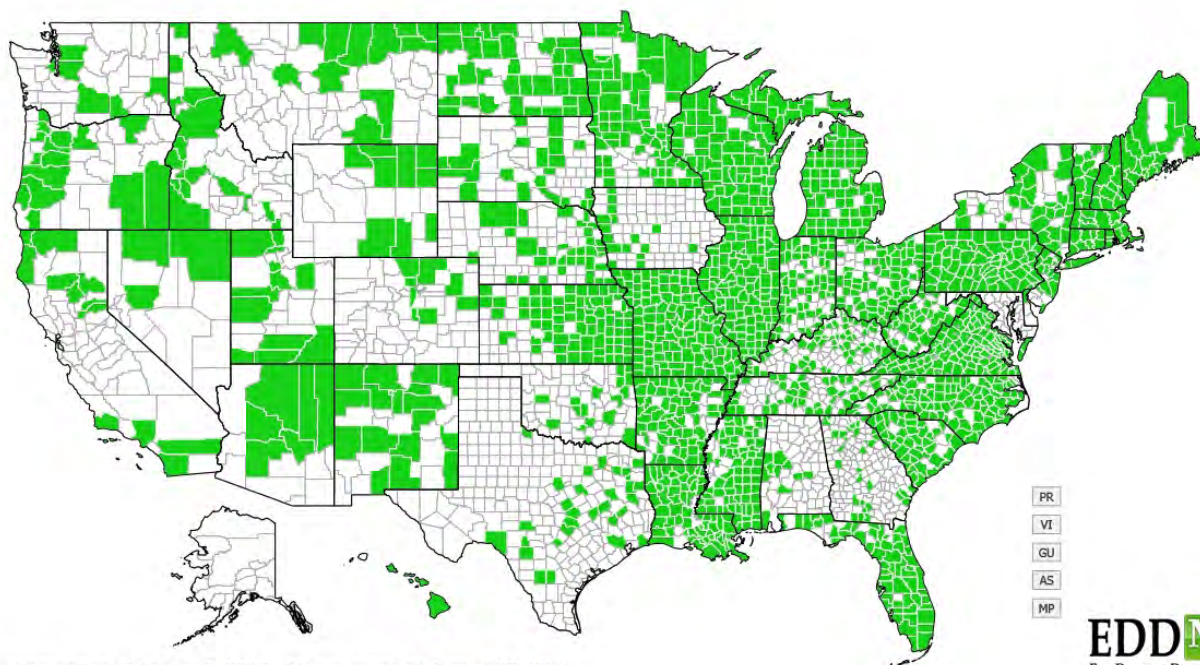
use the data. The USA National Phenology Network is an organization that creates a database. *Nature's Notebook* staff collects the data from citizen scientists, organizes the databases, and distributes data to scientists. Keeping these records is important. Scientists can analyze the information to learn about trends, or changes over time, in climate and phenology.

How Do Scientists Use Data From *Nature's Notebook*?

Scientists want to know how a changing climate will affect plants. One group of plants they study is invasive species. Ragweed is one plant that some scientists consider an invasive species because it is spreading as the climate warms. The phenology of ragweed requires a certain temperature, length of day, and number of days without freezing temperatures to start growing.

In 2014, scientific research predicted that ragweed would spread to more North American locations. The scientists believed it was spreading due to a changing climate which created conditions suitable for the plant's phenology. Scientists used citizen science data from *Nature's Notebook* to confirm the accuracy of their research conclusions about ragweed.

Ambrosia artemisiifolia



Ragweed is an agricultural weed that causes allergies in humans. Green areas on the map show counties where citizen scientists have observed ragweed. Photo courtesy of EDDMapS.

Glossary

accurate (ə kyə rət): Free from error.

adapt (ə dapt): To adjust to new conditions.

cue (kyū): A signal.

database (dā tə bās): A comprehensive collection of related data organized for convenient access, generally in a computer.

invasive species (in vā siv spē shēz): Any plant, animal, or organism that is not native to the ecosystem it is in and is likely to cause harm to the environment, the economy, or human health.

migrate (mī grāt): To move from one place to another.

protocol (prō tə kāl): A plan for a scientific experiment.

reliable (ri lī ə bəl): Giving the same results in repeated attempts.

trend (trend): A behavior pattern occurring and developing over a period of time.

Accented syllables are in **bold**. Marks and definitions are from <http://www.merriam-webster.com>. Definitions are limited to the word's meaning in the article.

FACTivity

Time Needed

One class period

Materials

(for each student or group of students)

- Computer (optional)
- Pen/pencil
- *Nature's Notebook* Field Datasheets
- Field guides (optional)
- Binoculars/magnifying glass (optional)

Become a citizen scientist by collecting phenology data from your school, town, or home using *Nature's Notebook* (https://www.usanpn.org/natures_notebook). Follow the directions below to start observations or visit the *Nature's Notebook*.

Website to learn about starting observations for your citizen science project (<https://www.usanpn.org/nn/guidelines>).

Methods

1. As a class, brainstorm up to five plants or animals that you would like to observe. These can be plant or animal species from *Nature's Notebook* "Campaign Species," or species discussed in class. Make sure that the chosen species are those that you know live nearby.
2. Choose an easily accessible location where your class can conduct observations. You can choose your schoolyard, your backyard, or a local park. If plants are being observed, remember to flag the individual plants your class is observing. Plastic flagging,



yarn, or string can be used to identify the study plant.

3. Your teacher will create a *Nature's Notebook* profile on the website. You and your classmates can submit observations to this profile. Once a profile is created, the "My Observation Deck" link allows your teacher to create an observation location. Give your location a name, such as "Riverview Middle School."
4. Next, your teacher will add the plants and/or animals that your class will observe.
5. Together with your teacher, review the protocol that you will use while observing

and recording. Each plant or animal observed will have a Field Datasheet that can be printed for your use (figure 4).

6. Conduct observations two or more times per week using the Field Datasheet for each species. The longer period over which you make observations and collect data, the more you will learn about the phenology of the species you chose.
7. How did your plant or animal change during your observations? Compare your observations to the observations of other citizen scientists that are collected for the same species on *Nature's Notebook*.

Trees and Shrubs *Deciduous*

Directions: Fill in the date and time in the top rows and circle the appropriate letter in the column below.

y (phenophase is occurring); n (phenophase is not occurring); ? (not certain if the phenophase is occurring).

Do not circle anything if you did not check for the phenophase. In the adjacent blank, write in the appropriate measure of intensity or abundance for this phenophase.



Species: **Cornus florida**

Common Name: **flowering dogwood**

Nickname: **flowering dogwood-1**

Site: **Sandy Creek Nature Center**

Year: **2016**

Observer: **null null**

	Date:	Date:	Date:	Date:	Date:	Date:	Date:	Date:
Do you see...	Time:	Time:	Time:	Time:	Time:	Time:	Time:	Time:
Breaking leaf buds	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____
Leaves	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____
Increasing leaf size	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____
Colored leaves	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____
Falling leaves	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____
Flowers or flower buds	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____
Open flowers	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____
Fruits	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____
Ripe fruits	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____
Recent fruit or seed drop	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____	y n ? ____
Check when data entered online:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Comments:								

Figure 4. A Field Datasheet produced by *Nature's Notebook*, like this one for flowering dogwood trees, can be made for each plant or animal species your class observes. Photo courtesy of *Nature's Notebook*.

The Monarch Larva Monitoring Project: Citizen Scientists Monitor Monarch Butterflies

With its familiar pattern of orange and black, the monarch is perhaps the best known butterfly in North America. Each year, adult monarchs migrate from winter roosts to summer grounds across North America.

Along the way, female butterflies lay eggs on milkweed; the eggs then hatch into caterpillars, also known as larvae. The larvae grow by feeding on milkweed (**figure 1**); through metamorphosis, they transform into the next generation of adult butterflies and continue their annual journey across thousands of miles. In the fall, the newest generation of adults flies south to the overwintering sites.

But now the monarch is in trouble. Due to habitat loss, patches of milkweed are fewer and farther between, so the number of monarch larvae is dwindling.

In the 1990s, researchers at the University of Minnesota decided to use citizen science to collect long-term data on monarch larvae and milkweed habitat in order to provide information that decisionmakers can use to help prevent the monarch's decline. The Monarch Larva Monitoring Project (MLMP) has grown to involve volunteers from across Canada and the United States.

Project Description

Participants in the program volunteer to monitor a particular site—often their own backyards—following a standard protocol. Through online or in-person training, the volunteers learn how to identify milkweed as well as the eggs, caterpillars, and pupae of monarch butterflies. They also learn about the monarch's annual cycle of breeding, migrating, and overwintering.



Figure 1. Monarch larva on milkweed plant. Photo courtesy of Becky Hansis-O'Neill.

Each year, volunteers record when milkweed plants first come out of the ground and how many are present at the site they are monitoring (**figure 2**). Then, on a weekly basis, they record the number of eggs and caterpillars they see on the milkweed (**figures 3 and 4**). They also have the option of collecting other useful data, such as the amount of rainfall or the relationship between a parasite and host.

The final step in the monitoring process is logging on to a secure website and entering the data collected into a master database.

Challenges

For citizen science projects, data validity can be a concern. Some say that nonscientists can't be trusted to collect reliable data. The project addresses these concerns by using a standardized protocol and requiring repeated observations of the same species in the same place over time. The MLMP offers in-person and online training. The MLMP project leaders carefully check the data before it is used for research purposes.

Another challenge is getting volunteers to report zeroes, or the lack of monarchs. As the monarch population declines, volunteers may find fewer and fewer monarchs during monitoring, which may discourage the volunteers and cause them to not want to collect or submit data. MLMP staff work with volunteers to highlight the importance of knowing where monarchs are not found, as well as where they are present.

Benefits and Outcomes

The project is successfully meeting its core purpose: to help scientists better understand how and why monarch populations are changing. As of 2015, project participants had monitored almost 1,100 sites in 43 States and 3 Canadian provinces, along with the Mexican State of Jalisco. Data provided by citizen scientists have allowed the scientific community to track the health of monarch populations and the habitats they depend on, forming the basis for a growing number of scientific publications.

Abridged from the Federal Crowdsourcing and Citizen Science Toolkit—Case Studies. For more information, visit <https://crowdsourcing-toolkit.sites.usa.gov/monitor-monarchs/>.



Figure 2. Citizen scientists walking sampling transect during Monarch Larva Monitoring Project monitoring. Photo courtesy of Laura Molenaar.

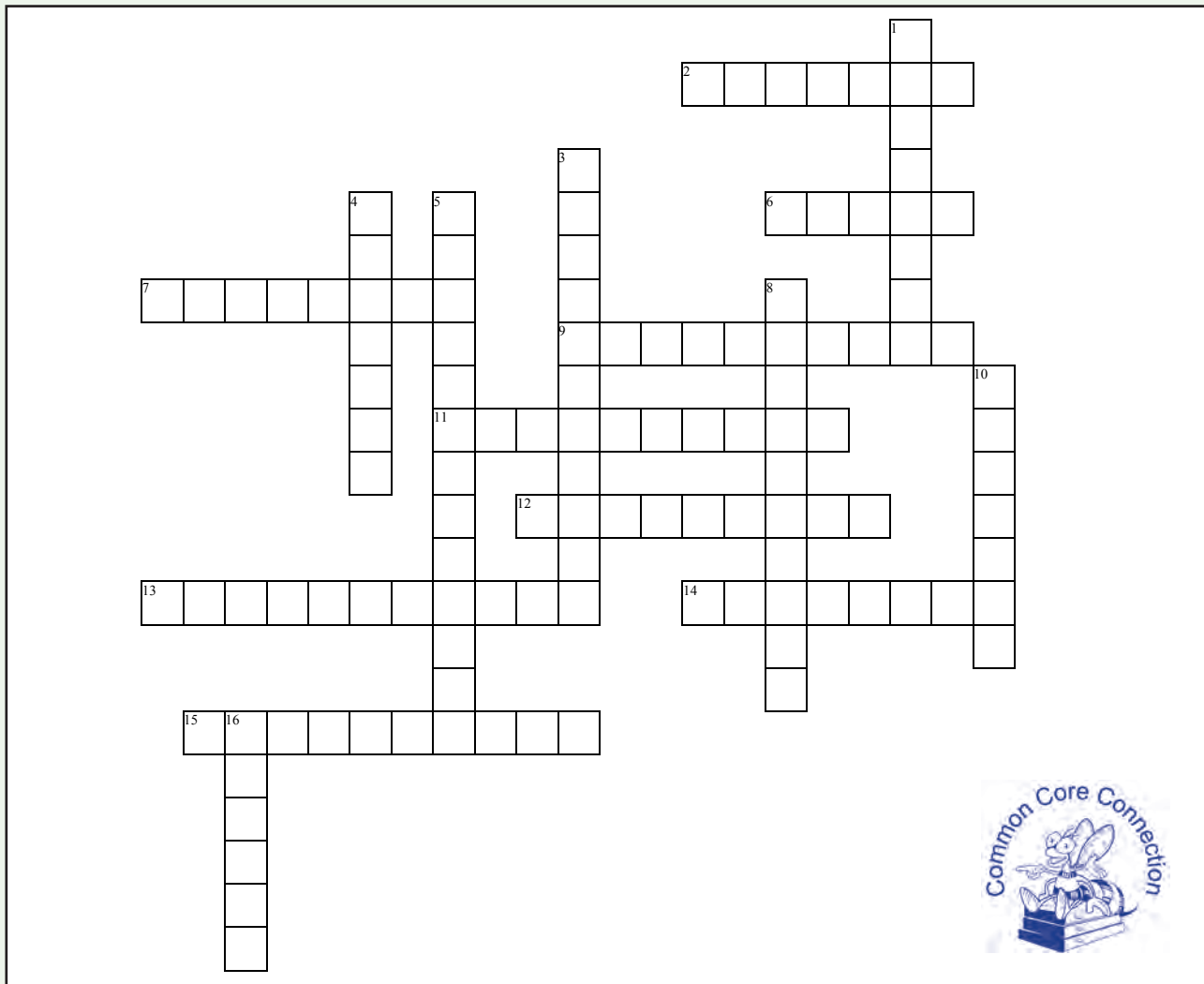


Figure 3. Monarch egg on milkweed plant. Photo courtesy of Wendy Caldwell.



Figure 4. Volunteers monitoring for Monarch Larva Monitoring Project. Photo courtesy of Kip Kiphart.

Citizen Science Crossword



Across

2. To watch, observe, listen to, or check (something) for a special purpose over a period of time.
6. To cause someone, or something, to decide not to do something.
7. A comprehensive collection of related data organized for convenient access, generally in a computer.
9. Being in the habit or custom.
11. To cause (something) to become more active and lively
12. Having a characteristic of moving from one place to another on a periodic basis.
13. Of, relating to, or being a method of using a resource so that the resource is not depleted or permanently damaged.
14. An animal, in this case a bird, that is a year old or in the second year after birth.
15. Being in danger or peril.

Down

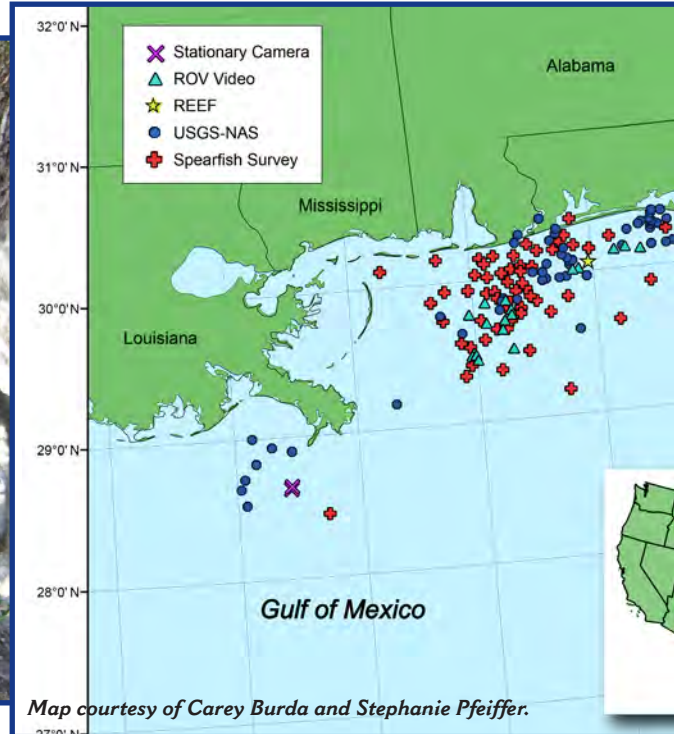
1. To avoid wasteful or destructive use of something.
3. A measure of how often a particular event will happen if something (such as tossing a coin) is done repeatedly.
4. To study or examine carefully.
5. Printed or written form of questions used to gather information.
8. (1) Not moving; (2) Staying in one place or position.
10. The feathers of a bird.
16. Living or growing naturally in a particular region.

Citizen Science eyeChallenge

Explain what each of these photos represents. You may write your explanation or hold a class discussion. If you write your explanation, use complete sentences, proper spelling and grammar, and appropriate punctuation.



Photo courtesy of James Holland.



Map courtesy of Carey Burda and Stephanie Pfeiffer.

Ambrosia artemisiifolia

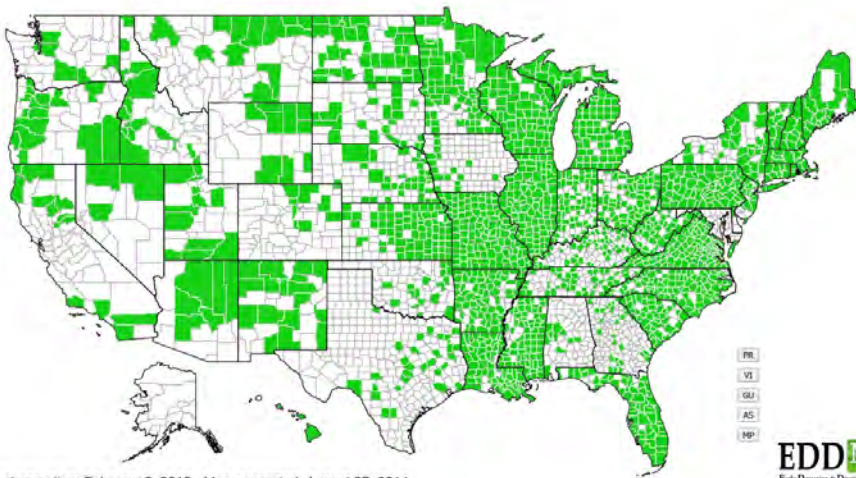


Photo courtesy of EDDMapS.

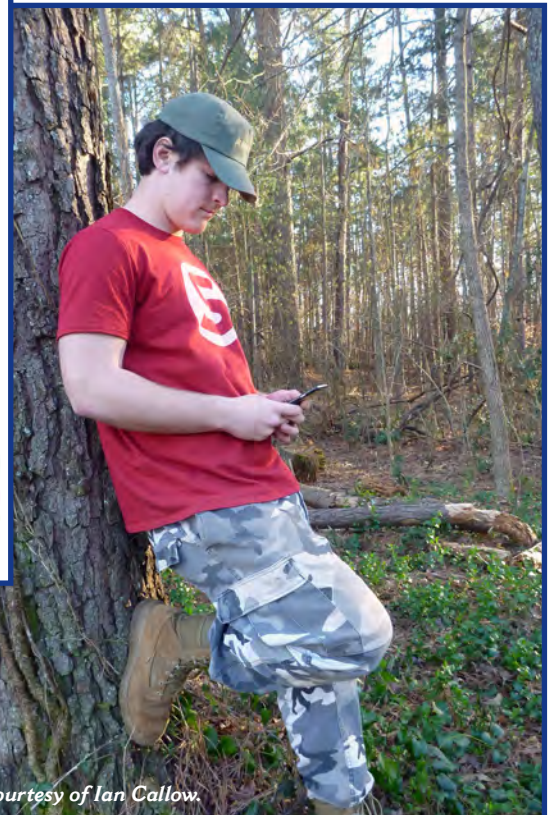


Photo courtesy of Ian Callow.

Citizen Science eyeChallenge

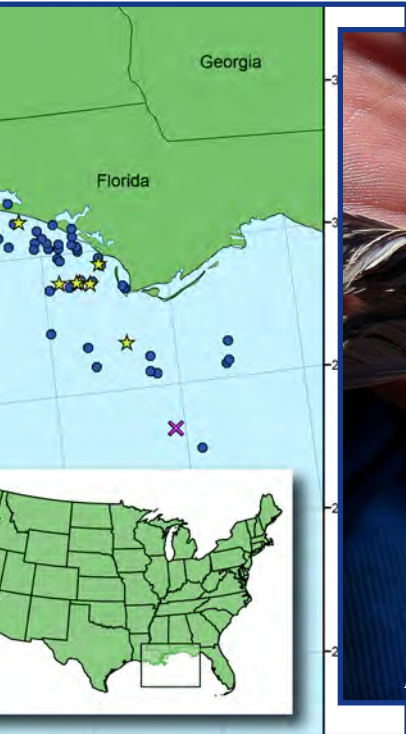


Photo courtesy of Aubree Benson.



Photo courtesy of Lad Akins.

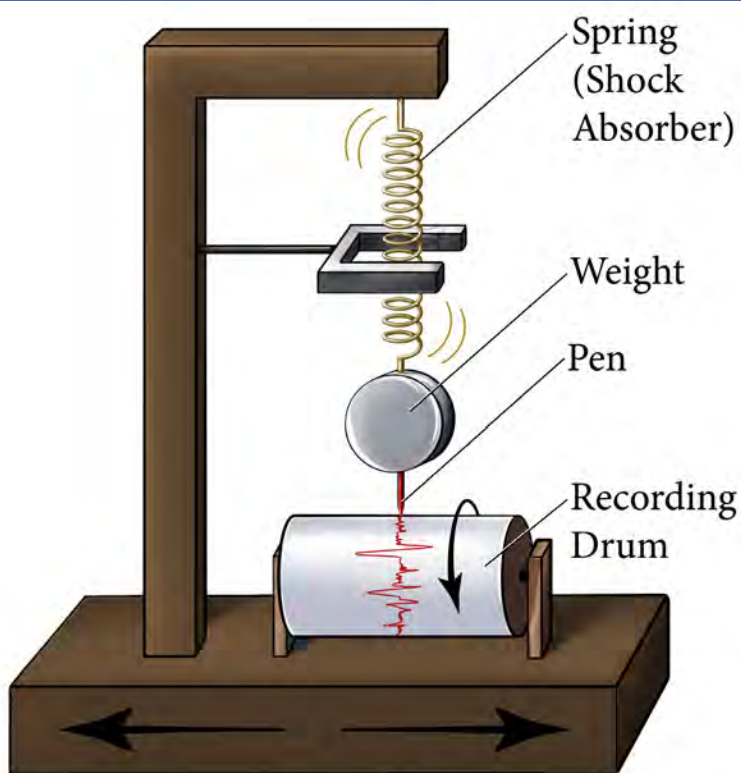


Illustration courtesy of Stephanie Pfeiffer.



Photo courtesy of Dolores Morrison.

Citizen Science in the Classroom

Meet Victoria Houser!

Victoria Houser

Forest Service Recreation Staff Officer

White River National Forest–Blanco Ranger District

"I have worked to develop citizen science projects with high school groups in Alaska and Colorado. These students have worked hard to demonstrate the value of citizen-based research and stewardship."



Follow the Spotlight Bee through this section to get more advice from Victoria Houser.



Photo courtesy of Victoria Houser.

How To Create a Successful Program

Step 1: Scope Out Your Problem

Start by brainstorming potential topics or problems with your students. Create a list of your students' areas of interest. As you think about potential topics, ask the class: Why does the topic matter? What research has been done in the past? What are the goals of this research?

Based on your discussions with the class, narrow the list of topics to five or less and look for citizen science projects associated with the areas of interest. A list of resources is available in the "Citizen Science Resources" on page 89 of this journal. Locate other citizen science projects by searching

the Internet. Compare and contrast the potential projects by examining each project's requirements for time, location, topic, equipment, costs, or skills. Choose the project that best fits your requirements and those of your students and your community.

Work with your students and school community to identify any barriers to completing the chosen citizen science project. How much does the project cost? How much time does the project require? Is safety an issue? Identify ways to overcome these potential barriers. Safety should always be a primary concern.



Victoria Houser says....

"The possibilities for citizen science projects are endless. Narrow down the choices by knowing your limitations, discussing the interests of students, and conducting research on your location.

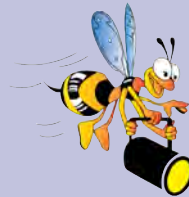
Contacting local stakeholders, such as a State natural resource agency, Federal natural resource agency, or natural resource nonprofit organization, is another good way of narrowing down the topic. Agencies and organizations can provide expertise and can potentially help complete the project."

Step 2: Design a Project

Once you have identified the citizen science project, work with your students to create goals and objectives. Goals are broad statements that highlight the potential positive outcomes of the project, such as: "A goal for this project is to improve school community awareness of a stream located in the schoolyard." Objectives are more specific, measurable, and, in many cases, relate to student learning. An example of an objective is: "Students will be able to explain the steps of the scientific method."

Work together with your students to create an inventory of the resources available to complete the project. What resources can the school provide? What resources are available from the local stakeholders or the people running the citizen science project?

Develop a plan for how the citizen science project should proceed. Include items such as timelines, participant roles (maybe provide a few examples of types of roles), scientific protocol, and how the results of the project will be used.



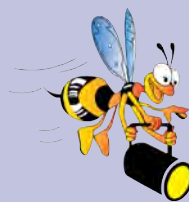
Victoria Houser says....

"Any time you go outside and observe the natural world, you are practicing citizen science. The next steps are recording the observations and making a plan to use the results of the observations. Create or use an existing protocol that is manageable for the student age level, replicable, and produces meaningful data. This component probably takes the most work. If you are contributing to an established citizen science project, the organization will provide the protocol. If you and your students create your own project, students should test the protocol before starting data collection.

Methodology should include an explanation of how the results will be used. Questions to think about include: What information is needed to answer our questions? How will we share our information with others?"

Step 3: Build a Community

Engage the students, stakeholders, and other community members in the project. Use the strengths of all participants, and make sure that each participant or group of participants knows their role. What resources do your students or stakeholders need?



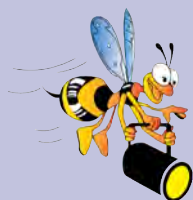
Victoria Houser says....

"Remember that unexpected results, or unsupported hypotheses, are important too. Catching no fish in a river tells us something!"

Step 4: Manage Your Data

Just like scientists, your students are collecting data to help answer a research question. If it is your own citizen science project, be prepared with a plan to handle and store your data. If you are contributing to an established citizen science project, the organization will have programs that help compile your data for you and provide access to it.

Work with your students to analyze the data. Analysis helps document and describe facts, detect patterns, develop explanations, test hypotheses, and check for error.



**Victoria
Houser
says....**

"Get "buy-in" from your students and other participants by allowing them to be leaders or decisionmakers in the project. Give them an opportunity to present their work and participants will be empowered by the real-life impacts of this work."

Step 5: Sustain and Improve

Successful projects require sustained participation and funding. Adapt to changes in participation, look for new resources, and evaluate your project continually. Consider making a newsletter or blog to update people on the progress of your project.



**Victoria
Houser
says....**

"Sharing results with others helps grow support for your project. Support from new participants, whether they are students or agencies, can contribute something toward the continuation of the project."

Citizen Science Resources



The following resources provide additional information about citizen science. A sample of citizen projects related to the articles in this journal is also included. Note that you may want to do a more extensive search for all existing projects related to your class's topic of interest to ensure the best possible project.

Note: Projects marked with an asterisk (*) use mobile devices, such as smartphones, to engage citizen scientists in the project.

General Citizen Science Resources

Federal Citizen Science Resources
<https://www.citizenscience.gov>

Forest Service Citizen Science
<https://www.fs.fed.us/working-with-us/citizen-science>

Cornell Lab Ornithology Citizen Science Toolkit:
<http://www.birds.cornell.edu/citscitoolkit/toolkit>

UK Environmental Observation Framework—Guide to Citizen Science:
<http://www.nhm.ac.uk/content/dam/nhmwww/take-part/Citizenscience/citizen-science-guide.pdf>

SciStarter:
<http://scistarter.com/>

Projects by Topic:

Natural Hazards

Precipitation Identification Near the Ground (PING):
<http://www.nssl.noaa.gov/projects/ping/>

Did You See It?:
<http://landslides.usgs.gov/dysi/form.php>

Did You Feel It?:
<http://earthquake.usgs.gov/earthquakes/dyfi/>

iCoast: Did the Coast Change?:
<http://coastal.er.usgs.gov/icoast/about.php>

Is Ash Falling?:
<https://www.avo.alaska.edu/ashfall/ashreport.php>

Marine and Coastal

Phytoplankton Monitoring Network:
<http://products.coastalscience.noaa.gov/pmn/>

*iNaturalist:
<http://www.inaturalist.org/>

*Nature's Notebook:
https://www.usanpn.org/natures_notebook

Marine Debris Tracker:
<http://www.marinedebris.engr.uga.edu/>

Coastal Observation and Seabird Survey Team:
<http://depts.washington.edu/coasst/involved/volunteer.html>

Marine Invasions Research Lab:
http://www.serc.si.edu/labs/marine_invasions/citizen_science/index.aspx

iCoast: Did the Coast Change?:
<http://coastal.er.usgs.gov/icoast/about.php>

Invasive Species

EDDMapS – Early Detection and Distribution Mapping System: <https://www.eddmaps.org/>

*iNaturalist:
<http://www.inaturalist.org/>

*Nature's Notebook:
https://www.usanpn.org/natures_notebook

*iMapInvasives:
<http://www.imapinvasives.org/>

Marine Invasions Research Lab:
http://www.serc.si.edu/labs/marine_invasions/citizen_science/index.aspx

U.S. Geological Survey Nonindigenous Aquatic Species Program:
<http://nas.er.usgs.gov/>

Birds

*eBird:
<http://ebird.org/>

Project FeederWatch:
<http://feederwatch.org/>

Neighborhood NestWatch:
http://nationalzoo.si.edu/scbi/MigratoryBirds/Research/Neighborhood_Nestwatch/

North American Bird Phenology Program:
<https://www.pwrc.usgs.gov/bpp/index.cfm>






































North American Breeding Bird Survey:
<https://www.pwrc.usgs.gov/bbs/index.cfm?CFID=12209626&CFTOKEN=18d778e2a9a6c045-2A65F0DA-F84D-567C-99918024DCEB14BD>













*iNaturalist:
<http://www.inaturalist.org/>
*Nature's Notebook:
https://www.usanpn.org/natures_notebook

Coastal Observation and Seabird Survey Team:
<http://depts.washington.edu/coasst/involved/volunteer.html>

Lend a Hand Care for the Land



<i>Which National Science Education Standards Can These Articles Address?</i>	Device-ive Science	All Over the Map	Lion in Wait	Invasion of the Song Snatcher
Science as Inquiry				
Abilities Necessary To Do Scientific Inquiry				
Understandings About Scientific Inquiry				
Life Science				
Regulation and Behavior				
Populations and Ecosystems				
Diversity and Adaptations of Organisms				
Earth Science				
Structure of Earth System				
Science in Personal and Social Perspectives				
Risks and Benefits				
Science and Technology in Society				
Understandings about Science and Technology				
Natural Hazards				
History and Nature of Science				
Science as a Human Endeavor				
Nature of Science				

<i>Which National Curriculum Standards for Social Studies Can These Articles Address?</i>	Device-ive Science	All Over the Map	Lion in Wait	Invasion of the Song Snatcher
Time, Continuity, and Change				
People, Places, and Environments				
Science, Technology, and Society				
Global Connections				
Individuals, Groups, and Institutions				
Civic Ideals and Practices				
Individual Development, and Identity				

What Is the U.S. Geological Survey?

The U.S. Geological Survey, a part of the Federal Government, is a



science organization that provides impartial information about the:

- Health of our ecosystems and environment
- Natural hazards that threaten us
- Natural resources we rely on
- Impacts of climate and land-use change
- Core science systems that help us provide timely, relevant, and useable information

<http://www.usgs.gov>

What Is the Cradle of Forestry in America Interpretive Association?



The Cradle of Forestry in America Interpretive Association (CFAIA) is a 501(c)3 nonprofit organization based in Pisgah Forest, North Carolina. The CFAIA strives to help people better understand ecology through recreation and education opportunities. Their projects include the following:

- Campground and recreation area management
- Educational programs and services in partnership with the Forest Service, including *Natural Inquirer*, *Investi-gator*, *Natural Inquirer Reader Series*, *NSI: Nature Science Investigator*, scientist cards, and Leaf Prints (formerly Nature-Oriented Parenting)
- 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 Historic Site

<http://www.cfaia.org>

What Is the Forest Service?



The Forest Service is part of the United States Department of Agriculture (USDA). The Forest Service is made up of thousands of people who care for the Nation's forest land.

The Forest Service manages 154 national forests and 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 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 this journal. Forest Service scientists work to solve problems and provide new information about natural resources so that we can make sure our natural environment is healthy, now and into the future.

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



Lend a Hand Care for the Land

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To file a program discrimination complaint, complete the USDA Program Discrimination Complaint Form, AD-3027, found online at http://www.ascr.usda.gov/complaint_filing_cust.html and at any USDA office or write a letter addressed to USDA and provide in the letter all of the information requested in the form. To request a copy of the complaint form, call (866) 632-9992. Submit your completed form or letter to USDA by: (1) mail: U.S. Department of Agriculture, Office of the Assistant Secretary for Civil Rights, 1400 Independence Avenue, SW, Washington, D.C. 20250-9410; (2) fax: (202) 690-7442; or (3) email: program.intake@usda.gov.

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Forest Service

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**Editorial Review Board—C.R. Anderson Middle School, Montana;
Ms. Hagengruber's 7th Grade Science Classes**



Photo courtesy of Liz Burke.



Photo courtesy of Liz Burke.

Website Resources

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

Facebook: Natural Inquirer
Twitter: @naturalinquirer

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

U.S. Geological Survey
<http://usgs.gov>

Federal Citizen Science Resources
<https://www.citizenscience.gov>

Forest Service Citizen Science
<https://www.fs.fed.us/working-with-us/citizen-science>

U.S. Geological Survey Citizen Science
<http://txpub.usgs.gov/myscience/>