

## Teacher Resource for:

Enhanced Remote Earthquake Triggering at Fluid-Injection Sites in the  
Midwestern United States

## Using This Teacher Resource

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## **GENERAL USE OF Science in the Classroom**

### **Student Learning Goals:**

Current views of science education emphasize that “one fundamental goal for K-12 science education is a scientifically literate person who can understand the nature of scientific knowledge.” (From *A Framework for K-12 Science Education*, National Research Council, 2012).

The U.S. National Academy of Sciences defines science as: “Any new finding requires independent testing before it is accepted as scientific knowledge; a scientist is therefore required to honestly and openly report results so that they can readily be repeated, challenged, and built upon by other scientists. Proceeding in this way over centuries, the community effort that we call science has developed an increasingly accurate understanding of how the world works. To do so, it has had to reject all dogmatic claims based on authority, insisting instead that there be reproducible evidence for any scientific claim.”

A very important student learning goal, central to any understanding of “the nature of scientific knowledge,” is to give each student an appreciation of how science is done.

This includes knowing why:

- Scientists must be independent thinkers, who are free to dissent from what the majority believes.
- Science can deal only with issues for which testable evidence can be obtained.
- All scientific understandings are built on previous work
- It is to be expected that one scientist’s conclusions will sometimes contradict the conclusions of other scientists.
- Science is a never-ending venture, as the results from one study always lead to more questions to investigate.

## Using This Resource

### Learning Lens:

The Learning Lens tool can be found on the right sidebar of each resource and is the source of annotations. Clicking on any of the headings will result in corresponding text of the research article being highlighted. A second click on the highlighted text will produce a text box containing more information about that particular piece of text. Below is an example of the Glossary function of the Learning Lens in use.

Audience

High School

University

Edit

A Tiny Fungus is Causing Big Problems

TOPIC Biology



EDITOR'S INTRODUCTION

Despite their size, ecosystems are fragile and easily disrupted. The introduction of a novel disease can have serious impacts on naive wildlife populations, which in turn will affect the strength of the entire ecosystem.

White-nose syndrome, a fungal infection affecting bats, has recently spread from upstate New York to West Virginia. The fungal infection makes bats restless over winter, causing them to exit hibernation early, which in turn leads to a depletion of energy stores and, ultimately, death. This research article has analyzed population data collected on bats in the northeastern United States for the past 30 years and shows that, due to White-nose syndrome, the once abundant bat is heading for regional extinction in the next 16 years. This complete loss of an insectivorous mammal will undoubtedly have repercussions on ecosystem integrity. What, if anything, can be done to slow this regional extinction?

ABSTRACT

White-Nose Syndrome (WNS) is an emerging disease affecting hibernating bats in eastern North America that causes mass mortality and precipitous population declines in winter hibernacula. First discovered in 2006 in New York state, WNS is spreading rapidly across eastern North America and currently affects seven species. Mortality associated with WNS is causing a regional population collapse and is predicted to lead to regional extinction of the little brown myotis (Myotis lucifugus), previously one of the most common bat species in North America. Naive diseases can have serious impacts on naive wildlife populations, which in turn can have serious impacts on ecosystem integrity.

Learning Lens

Chytridiomycosis is a disease caused by the fungal pathogen "Batrachochytrium dendrobae" and is responsible for many amphibian deaths and extinctions around the world. For a related "Science" news story, please visit: <http://www.sciencemag.org/content/336/6092/607.full>

REPORT

Emerging infectious diseases are increasingly threatening the health of humans and wildlife. Introductions of disease into naive wildlife populations have led to population declines or local extinctions of different species in the past few decades, including amphibians from chytridiomycosis (5, 6), rabbits from myxomatosis in the United Kingdom (7), Tasmanian devils from infectious cancer (3), and birds in North America from West Nile virus (8). Here we demonstrate that White-Nose Syndrome (WNS), an emerging infectious disease, is causing unprecedented mortality among hibernating bats in eastern North America and has caused a population collapse that is threatening regional extinction of the little brown myotis (Myotis lucifugus), a once widespread and common bat species.

WNS is associated with a newly described psychrophilic fungus (Geomyces destructans) that grows on exposed tissues of hibernating bats, apparently causing premature arousals, aberrant behavior, and premature loss of critical fat reserves (9, 10) (Fig. 1). The origin of WNS and its putative pathogen, G. destructans, is uncertain (9). A plausible hypothesis for the origin of this disease in North America is introduction via human trade or travel from Europe, based on recent evidence that G. destructans has been observed on at least one hibernating bat species in Europe (11). Anthropogenic spread of invasive pathogens in wildlife and domestic animal populations, so-called pathogen pollution, poses substantial threats to biodiversity and ecosystem integrity and is of major concern in conservation efforts (1, 2).

THOUGHT QUESTIONS

- What is the purpose or objective of this study?
- Why is this study important?
- What is the conclusion of this study?
- What is the evidence for this conclusion?
- Are there any doubts that this conclusion is right?
- What would you do next?

LEARNING LENS

Click on a category below to display annotations. You can find more information by clicking the highlighted text to the left.

GLOSSARY

PREVIOUS WORK

AUTHOR'S EXPERIMENTS

CONCLUSIONS

NEWS AND POLICY LINKS

CONNECT TO LEARNING STANDARDS

REFERENCES AND NOTES

Related Science News

Paper Details

Questions?

Activities

Teaching Resources

Contact Us

An example of the resource with the Glossary, Previous Work, Author's Experiments, News and Policy Links, and References and Notes tools turned on. The Glossary tool is in use.

### **Learning Notes:**

Learning Notes accompany each figure and are designed to help students deconstruct the methods and data analysis contained within each figure.

### **References:**

The Reference section of each resource is annotated with a short statement about how or why each reference relates to the current research study.

## **Suggestions for Classroom Use:**

Four alternative ways to use the SitC reading, questions, and activities:

1. Assign to small groups to complete during class
2. Assign different sections of the article to small groups to complete during class. Use class presentations or jigsaw to teach the entire class what is in the article.
3. Assign to individual students to complete during class or as homework.
4. Assign as an extra credit project.

Interactive student engagement ideas for use after reading the article:

1. Have students write answers to discussion questions (for example, those linked to the standards or those linked to the diagrams).
2. Go over the abstract, as well as information about the purpose and structure of an abstract, and have students write their own abstracts for the articles in language that could be best understood by their peers.
3. Have students edit the current version of the article, or parts of the article, to a simpler reading level.
4. Have students, working alone or in small groups, use the annotated list of references to explain how the scientists who wrote this article built on the published work of at least one independent group of scientists in making their discoveries. In the process, did they produce data that supports the findings of the earlier publication that they have cited in the text? In what way does this article support the statement that scientific knowledge is built up as a “community effort”?
5. Use the article and discussion questions linked to the standards and the diagrams for a teacher-led classroom discussion. The discussion can focus on the nature of science and scientific research, as well as on the science in the article itself.
6. Have students give a classroom presentation about the article, parts of the article, or their answers to discussion questions.

## **ARTICLE-SPECIFIC MATERIALS**

### **Student Learning Goals:**

- Connections to the nature of science from the article
  - How does human activity influence earthquake frequency?
  - What can we learn from this data?
- The importance of this scientific research
  - To better understand the consequences of natural gas development (and similar technologies).
- The actual science involved
  - seismic measurements
  - investigation of dynamic triggering
  - analysis of Advances National Seismic System (ANSS) data
  - statistical analysis

## **Connect to Learning Standards:**

This resource connects to four sets of learning standards:

Discussion Questions related to these standards are found in [Resources for Interactive Engagement](#)

### **1. The AP Environmental Standards**

<http://apcentral.collegeboard.com/apc/public/repository/ap-environmental-science-course-description.pdf>

- Earth Systems and Resources
  - Earth Science Concepts (Geologic time scale; plate tectonics, earthquakes and volcanism; seasons; solar intensity and latitude) (page 6)
- Population
  - Human Population
    - Impacts of population growth (Hunger; disease; economic effects; resource use; habitat destruction). Found on page 7.

### **2. The Science and Engineering Practices contained in the Next Generation Science Standards**

[http://www.nap.edu/openbook.php?record\\_id=13165&page=41](http://www.nap.edu/openbook.php?record_id=13165&page=41)

- Practice 1: *Asking questions.*
- Practice 2: *Developing and using models.*

### **3. The Common Core English and Language Arts Standards**

<http://www.corestandards.org/ELA-Literacy/RST/11-12>

- RST.11-12.7: *Integrate and evaluate multiple sources of information presented in diverse formats and media in order to address a question or solve a problem.*

## **Summary of the Article for the Teacher:**

*It is recommended that this not be used by students in place of reading the article.*

### **General Overview:**

One predictable feature of earthquakes is that they are completely unpredictable. Or are they? Scientists are beginning to collect data indicating that a range of human activity, including hydraulic fracturing, can induce earthquakes. How is this data analyzed? What can we learn from this data, and will it allow us to predict, or even prevent, future earthquakes?

### **Topics covered:**

- seismic measurements
- investigation of dynamic triggering
- analysis of Advances National Seismic System (ANSS) data
- statistical analysis
- environmental impacts

### **Why this Research is Important:**

Hydraulic fracking is a major environmental concern in the United States. How do scientists collect data on how this practice affects the environment? How are these data properly analyzed? What can this data tell us about the environmental impact of emerging technologies? What else can we learn from how the earth reacts to these new stresses?

### **Methods used in the Research:**

- seismic analysis
- statistical analysis

### **Conclusions:**

The authors argue that the presence of naturally triggered earthquakes (by seismic waves) at fluid injection sites shows that the faults in the region have been weakened and brought close to failure by the infiltration of fluid.

### **Areas of Further Study:**

How can scientists use this new information to refine current natural gas extraction?



## **Resources for Interactive Engagement:**

### **1. Discussion Questions Associated with the Standards**

#### **The AP Environmental Standards**

##### *Earth Systems and Resources*

*Earth Science Concepts (Geologic time scale; plate tectonics, earthquakes and volcanism; seasons; solar intensity and latitude) (page 6)*

- How are plate tectonics related to earthquakes?
- As stress on the earth increases (through drilling, for example), how will plate tectonics be influenced?
- How will resulting earthquakes be influenced?
- Do you think this stress on the earth is worth recovering natural gas for?

##### *Population*

##### *Human Population*

*Impacts of population growth (Hunger; disease; economic effects; resource use; habitat destruction). (page 7)*

- As human population increases, what happens to the energy demands of the earth?
- How will this influence both plate tectonics and earthquakes?

#### **The Science and Engineering Practices contained in the Next Generation Science Standards**

##### *Practice 1: Asking questions.*

- How is asking questions an important part of scientific research?
- What are some other “big questions” in geology? Select one of your “big questions” and narrow it down to a question that could be investigated.

##### *Practice 2: Developing and using models.*

- Does the model the authors built work like they had envisioned?
- What can we learn from this model?
- If this model works, what is the next step?

## **The Common Core English and Language Arts Standards**

*RST.11-12.7: Integrate and evaluate multiple sources of information presented in diverse formats and media in order to address a question or solve a problem.*

- Why did the authors investigate earthquake data at more than one location?
- How are these locations similar?
- How do these locations differ?
- How do the scientists integrate data from different locations together?

## **2. Activities connecting to the data shown in the Article**

The Activities are linked to in the tool bar along the bottom of each resource. Activities linked to this particular resource contain raw data from the authors that the students will be able to work with directly.