

**Teacher Resource for:
Ongoing drought-induced uplift in the western United States.**



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GENERAL USE OF Science in the Classroom

Student Learning Goals:

“One fundamental goal for K-12 science education is a scientifically literate person who can understand the nature of scientific knowledge.”¹

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.”

An 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.

¹ *A Framework for K-12 Science Education*, National Research Council, 2012

Using This Resource

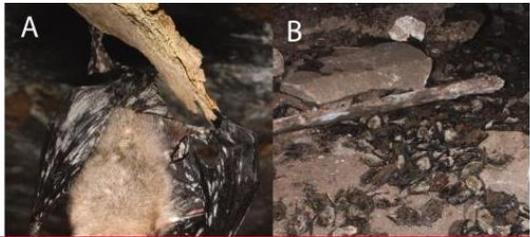
Learning Lens:

The Learning Lens tool can be found on the right sidebar of each resource and is the source of annotations. Click on the headings to highlight portions of the text of the corresponding research article. A subsequent 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.

ABSTRACT
[White-Nose Syndrome \(WNS\)](#) is an emerging disease affecting hibernating bat mortality and precipitous population declines in winter [hibernacula](#). First discovered spreading rapidly across eastern North America and currently affects seven species, 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. Novel diseases can have serious impacts on [naive wildlife populations](#), which in turn can have substantial impacts on ecosystem integrity.

REPORT
[Emerging infectious diseases](#) are increasingly recognized as [direct and indirect agents of extinction](#) of free-ranging wildlife (1–4). [Introductions of disease into naive wildlife populations](#) have led to serious 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).



Learning Lens

A species of bats:
http://www.mnh.si.edu/mna/image_info.cfm?species_id=199

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

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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.

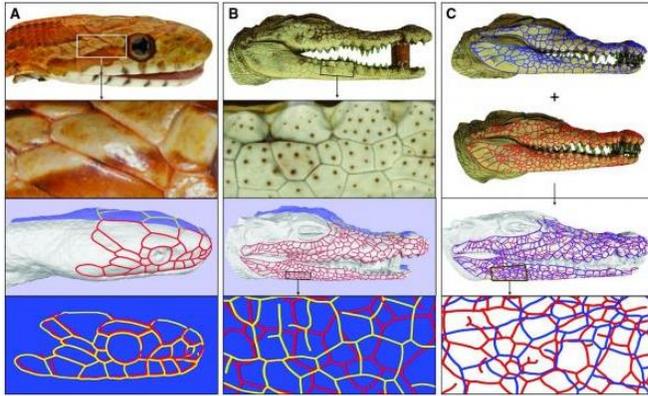


Fig. 1. Spatial distribution of head scales. (A) Head scales in most snakes (here, a corn snake) are polygons (two upper panels) with stereotyped spatial distribution (two lower panels): left (yellow) and right (red) scale edges overlap when reflected across the sagittal plane (blue). **(B)** Polygonal head scales in crocodiles have a largely random spatial distribution without symmetrical correspondence between left and right. **(C)** Head scales from different individuals have different distributions of scales' sizes and localizations (blue and red edges from top and bottom crocodiles, respectively).

Method: 3D geometry and color-texture reconstruction

Panel A

Panel B

Panel C

The authors took 120 color pictures of each animal to create detailed, three-dimensional models of reptile heads. Watch this video in which the authors further explain their modeling methods:

<http://www.sciencemag.org/content/suppl/2012/11/29/science.1226265.DC1/1...>

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- REFERENCES AND NOTES

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.

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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

Learning Lens

This paper showed that while both physical activity, like running, and living in an enriched environment can result in the generation of new hippocampal neurons in mice, a combination of the two activities leads to even greater rates of neurogenesis.

Thought Questions

Thought Questions are located above the Learning Lens in the right sidebar of each resource. These questions were written to be universal and applicable to any primary research paper. Thought questions do not have a single answer, or a correct answer for that matter, and can be used to stimulate discussion among students.

Science in the Classroom
A collection of annotated research papers and accompanying teaching materials

Audience: High School **University** Edit TOPIC Biological

Lemmings: They're What's for Dinner

Science
Brain Disease

EDITOR'S INTRODUCTION
Cyclic Dynamics in a Simple Vertebrate Predator-Prey Community.
Gilg *et al.*

Scientific studies often involve more than one discipline. In this case of lemming population dynamics, scientists use both ecology-related methodology to collect data in Greenland, and mathematical equations to construct a predictive model. Similar to the cyclic dynamic described in this study, this interdisciplinary research would not have been complete if one of these two scientific disciplines had been missing.

annotated by *Fanny Bernardon*
original paper published 10/31/2003
annotations posted on 1/31/14

ABSTRACT
The collared lemming in the high-Arctic tundra in Greenland is preyed upon by four species of predators that show marked differences in the numbers of lemmings each consumes and in the dependence of their dynamics on lemming density. A predator-prey model based on the field-estimated predator responses robustly predicts 4-year periodicity in lemming dynamics, in agreement with long-term empirical data. There is no indication in the field that food or space limits lemming population growth, nor is there need in the model to consider those factors. The cyclic dynamics are driven by a 1-year delay in the numerical response of the stoat and stabilized by strongly density-dependent predation by the arctic fox, the snowy owl, and the long-tailed skua.

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THOUGHT QUESTIONS

1. Why is this study important?
2. What is the objective?
3. What are the conclusions?
4. What is the supporting evidence?
5. Are there any doubts that this conclusion is right?
6. What would you do next?

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Suggestions for Classroom Use:

In addition to the thought questions discussed above, other resources are provided for use in the classroom. These can be found toward the end of the teacher guides associated with each specific article and include:

1. Discussion questions specific to the article, related to the standards, and/or associated with the figures.
2. Activities tied to the articles.

Some ways to use the *Science in the Classroom* articles:

1. Assign to student groups to read and discuss during class.
2. Assign small sections of the article to student groups to read and discuss during class, with the expectation that they will present or use jigsaw to teach the entire class what is in their part of the article.
3. Assign to individual students to complete during class or as homework.
4. Assign reading as an extra credit project.

Some ideas for interactive student engagement after reading the article:

1. 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 understood by their peers.
3. Have students edit the article, or parts of the article, to a simpler reading level.
4. Have students, 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

Connections to the nature of science from the article

- How can we monitor groundwater loss at a regional scale?
- What are some ways we can use GPS stations to learn about ground movement?
- How can water loss effect stress and strain?
- How do scientists present data and use statistics?

The importance of this scientific research

- GPS stations can be used to monitor groundwater loss at regional scales, and, in the future, may be used to monitor long-term effects of regional climate change.

The actual science involved

- Geology (elastic rebound)
- Hydrology
- Statistics

Connect to Learning Standards:

The AP Environmental Science Standards

http://media.collegeboard.com/digitalServices/pdf/ap/10b_2727_AP_Biology_CF_WEB_110128.pdf

- I. Earth Systems and Resources. C. Global Water Resources and Use (Fresh water/salt water; ocean circulation; agricultural, industrial, and domestic use; surface and groundwater issues; global problems; conservation)

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

<http://www.nextgenscience.org/sites/ngss/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf>

- Practice 3: Planning and carrying out investigations
- Practice 5: Using mathematics and computational thinking
- Practice 7: Engaging in argument from evidence

The AP Statistics Standards

<http://media.collegeboard.com/digitalServices/pdf/ap/ap-statistics-course-description.pdf>

- I. Exploratory analysis of data makes use of graphical and numerical techniques to study patterns and departures from patterns
- II. *Data must be collected according to a well-developed plan if valid information is to be obtained.*

The Common Core English and Language Arts Standards

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

- Integration of Knowledge and Ideas: CCSS.ELA-Literacy.RST.11.12.8: Evaluate the hypotheses, data, analysis, and conclusions in a science or technical test, verifying the data when possible and corroborating or challenging conclusions with other sources of information.

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:

Groundwater is a large source of fresh water for most of the western United States. Being, of course, beneath the surface can make it quite a challenge to monitor, especially at the regional scale. However, ways we can keep track of changes in this most valuable resource are evolving. A series of GPS stations known as PBO have been placed across the western United States to measure plate movement. These stations have been used in the past to measure ground motion along faults and track magma movement beneath volcanoes. What if we could use these same stations to measure regional changes in the most valuable of resources: groundwater. Scientists now are presenting these stations as way to monitor regional and global scale climate change.

Topics Covered:

- Statistical analysis and inference
- Time series analysis (including trend removal)
- Loading effects
- Inversion modeling
- Drought
- Remote sensing

Why this Research is Important:

This research presents a novel method to measure surface deformation related to interannual hydrological changes. The method uses GPS stations, which can provide smaller scale (local) measurements on otherwise difficult to measure parts of the hydrological system. They demonstrate the method's effectiveness by applying it to the recent drought in the western United States.

Methods used in the Research:

- Secular trend removal
- Seasonal trend loss method
- Data selection
- Statistical analysis
- Inversion and modeling
- Error analysis (statistical and checkerboard tests)
- Stress calculations

Conclusions:

- There is an area-integrated water deficit in the western United States of 240 gigatons (as of March 2014).
- The amount of stress change caused by water loss is not enough to affect seismicity.
- GPS stations can measure loading changes in wet and dry conditions at interannual scales
- GPS provides a method to measure water loss at a finer scale than other methods such as satellite measurements (GRACE). However, combining GPS and satellite data together should produce good measurements of terrestrial water storage at local, regional, and global scales.

Areas of Further Study:

- What can we learn about the hydrological observing network by adding GPS stations to existing measurements?
- What are the long-term effects of regional climate change?

Resources for Interactive Engagement:

Discussion questions associated with background information

1. When groundwater is depleted, why does the ground rise up instead of subside?
2. Do you think GPS stations used in this study have more vertical or horizontal motion?
3. What other geologic processes cause the earth to have vertical displacement?
4. Why are droughts so common in the western United States, and why might the most recent (2013) drought be one of the worst so far?

Discussion questions associated with methods

1. Do you think the GPS stations the authors excluded from their analysis are valid? Why or why not?
2. How do the authors go from having a series of data points at each station to an estimation of the total water loss?
3. How do the authors remove information about seasonal rainfall variations?

Discussion questions associated with analysis

1. Why is it important the authors prove that GPS can measure surface loading in dry and wet conditions?
2. What is the smallest scale in which the GPS stations can resolve loading differences?
3. What might be some methods to get even higher resolution data?

Discussion questions related to conclusions and future research

1. Why is this research so exciting; what new things does this article bring to science?
2. How does using both GPS and satellite data improve our understanding of the hydrologic system in the United States?

Discussion questions associated with the figures

Fig. 1: Would the data show more or less variability if the thin red lines (standard deviation) were farther apart?

Fig. 2: What trend does this figure show from 2011 to 2014?

Fig. 3: Which areas have experienced the most loading deficit? The least? How does this compare to Fig. 4?

Fig.4: Do your own comparison of rainfall and vertical displacement patterns from 2011 to 2014. Do you agree or disagree with the authors' interpretation?