

# Dead Fish in Bear Pond: Paleoecology and Clues at the Core

by

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## Part I – The Problem

Ivan and Kristin were two college students pursuing careers in the field of biology. They first met when taking General Botany at Dartmouth College in New Hampshire.

Every summer Ivan would drive up the east coast to his family's camp near Bear Pond, Maine. After a long year of difficult college classes, he planned on having an enjoyable and relaxing summer. He had also invited Kristin to spend two weeks with him at their family camp. He was excited to show her the beautiful scenery, woods and coastlines that define Maine. After arriving, Ivan decided to give Kristin a tour around the small town and then hike to Bear Pond by sunset. On their hike, they chatted as they walked along.

"I can't wait for you to see how majestic the woods and pond look during the summer months. Ever since I was little, it's been my favorite place to clear my mind. It even inspired me to study biology," explained Ivan.

"Sounds exciting! Maybe if it's still warm enough once we reach the lake we can take a dip to cool off," suggested Kristin.

When they arrived at the pond, Ivan was in shock. It was nothing like he remembered. The woods surrounding the lake seemed dry, thin and unhealthy, almost ghostly looking. More shocking, however, were the countless dead fish washed up on the shore. "Why are there so many dead fish? What's killing all the trees?" Kristin asked.

"I'm not sure, but I don't think we should swim here. Let's go back to the camp and ask my parents if they have any idea what's happening," Ivan replied.

### Questions

1. What could have caused the recent death of plants and fish in this area? Brainstorm a list of possibilities.
  
  
  
  
  
  
  
  
  
  
2. Choose one of the ideas that you listed and write a testable hypothesis. Describe how you would test this hypothesis with an experiment. Share your experimental design with your colleague sitting next to you.

## Part II – Is Acid Rain to Blame?

When they arrived back at Ivan's camp, they told his parents what they had observed. His parents mentioned that other landowners in the area had noticed similar conditions at their camps. Ivan's parents recalled reading a news story from the University of Maine that talked about the influence of acid rain on forests, lakes and streams in the area.

The researchers were examining the influence of acid on a local watershed near Bear Brook and had established a long-term research study that began in the 1980s. In the study half of the watershed was treated with chemical additions of nitrogen and sulfur (in the form of  $(\text{NH}_4)_2 \text{SO}_4$ ) to examine the effects of acid deposition on surface waters (BBWS, University of Maine, 2017).

"Research scientists at the university might understand the influence of acid rain on lakes and may have some insight on what is happening at the camps," said Ivan.

"I think we should contact them and dig deeper into how acid rain is formed and what impact it has on the environment," Kristin replied.

"Great idea!" exclaimed Ivan. "But maybe we should do a little research first to brush up on our knowledge of acid rain."

### Questions

3. What is an acid?

4. What is acid rain?

Ivan and Kristin had a conversation the next day with Dr. Karrie Simons at the University of Maine. During the conversation, they took notes on what was said. Here is what they jotted down:

*Over the past decades there has been a drastic increase in sulfur dioxide ( $\text{SO}_2$ ) and nitrogen oxides ( $\text{NO}_x$ ) being emitted into the air. The largest source of  $\text{SO}_2$  emissions is the burning of fossil fuels by power plants and similar industrial processing (EPA: <<https://www.epa.gov/so2-pollution/sulfur-dioxide-basics>>). The sulfur dioxide reacts with water, oxygen, and other chemicals to form sulfuric and nitric acids. With increases in human populations in the area, fuel emissions (another source of  $\text{SO}_2$  and  $\text{NO}_x$ ) have also been on the rise. The acidic emissions fall to Earth in both wet (rain, snow, fog, hail, and dust) and dry (particles and gases) forms. As this acid rain falls to the ground, it can negatively influence vegetation and wildlife. This is a possible reason for the fish and tree death.*

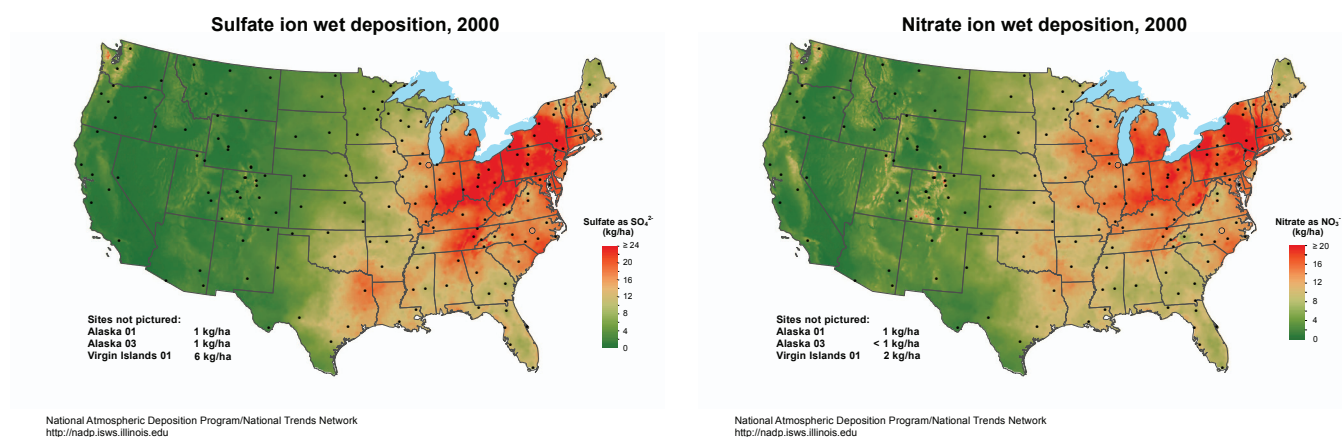
*Many organisms are sensitive to acidic conditions. Acidic water flowing through soil can also cause a leaching of aluminum and the removal of nutrients and minerals necessary for plant growth (EPA, 2017).*

### Questions

5. How is acid rain formed?

6. How does changing the pH of an ecosystem affect aquatic organisms?

Kristin and Ivan were curious if high  $\text{SO}_2$  and  $\text{NO}_x$  rates had been recorded elsewhere in the country. They asked Dr. Simmons and she sent them home to examine a few maps from the National Atmospheric Deposition Program (NADP) showing the acidity of different regions within the United States. The following maps were created from 250 different monitoring sites throughout the United States.



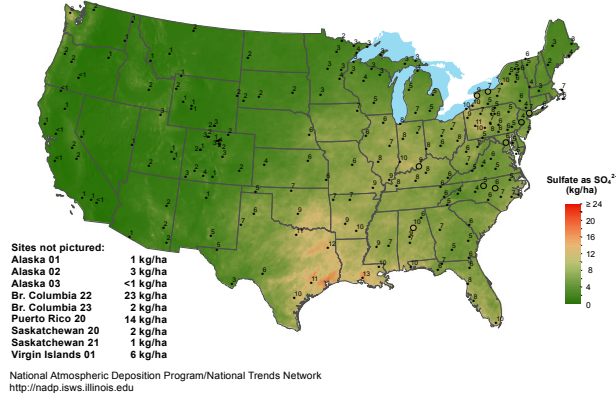
### Questions

- Examine the map of  $\text{SO}_2$  and  $\text{NO}_x$  emissions. What patterns do you observe? Why do you think these patterns exist?
- Predict what a map of acid rain ( $\text{H}^+$ ) might look like based on your interpretation of  $\text{SO}_2$  and  $\text{NO}_x$ . Record areas of high and low deposition on the map below.

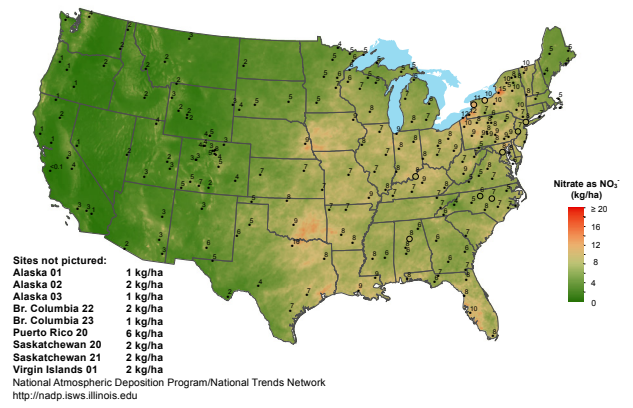


- These maps are from data collected during 2000. How do you think these maps compare to current  $\text{SO}_2$ ,  $\text{NO}_x$  and  $\text{H}^+$  maps and why?

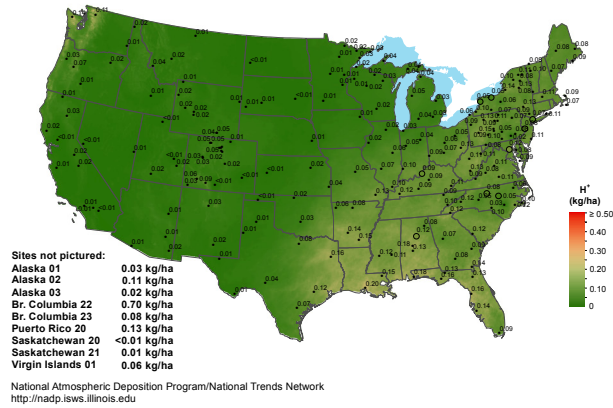
Sulfate ion wet deposition, 2015



Nitrate ion wet deposition, 2015



Hydrogen ion wet deposition from measurements made at the Central Analytical Laboratory, 2015



10. Why do you think the maps look so dramatically different from 2000 to 2015?



## Part III – Using Paleocology to Identify Historical Patterns

Kristin and Ivan wondered whether there was a way to determine if the rain had always been acidic or if this was a new development. They wondered if water quality data gathered in the past could be used as a comparison to current conditions. They called up Dr. Simons to see if she knew of such data. Dr. Simons said there was no historical water quality data for that region but there were other ways of inferring changes in pH over time. Since Kristin and Ivan were biology majors, they were familiar with biological water quality indicators.

Diatoms were the first thing that came to mind. Diatoms are a major group of photosynthesizing algae that are unicellular and composed of a silica-based cell wall. Diatoms are sensitive indicators of environmental change. They have been used to infer changes in lake level, temperature, nutrients, light and numerous other parameters over long periods. Could diatoms be used to see how the pH of Bear Pond had changed over time? Kristin and Ivan did a little research and found out the answer: *yes!*

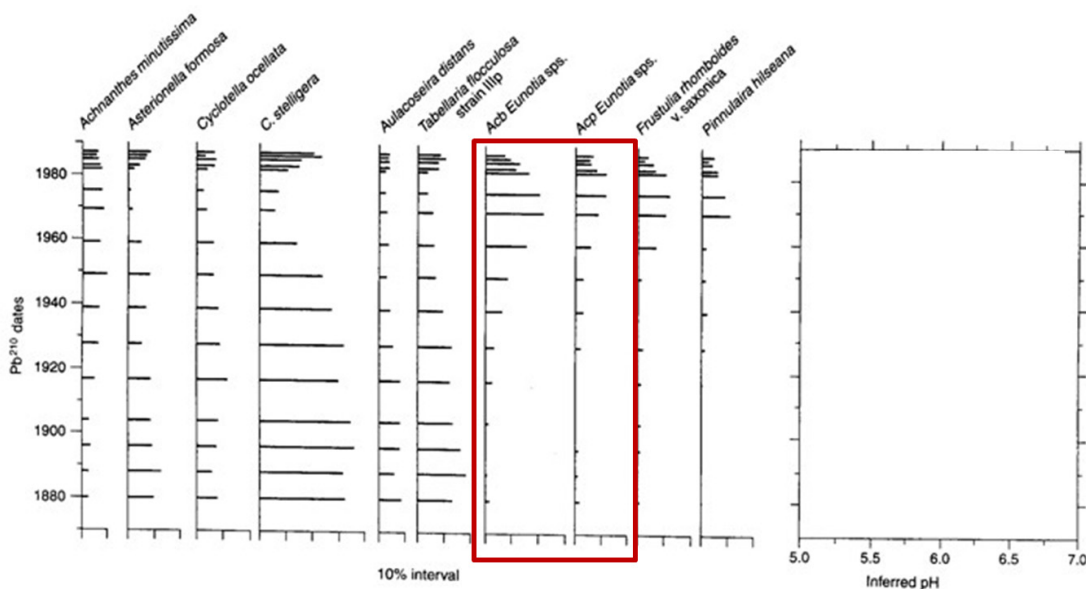
One of the earliest ways diatoms were used by scientists was to reconstruct lake histories; more specifically, diatoms have been used to determine that acid rain was real and affecting ecosystems in the Northeast. Diatoms provide an understanding of how pH changes over time because certain species of diatoms are very sensitive to pH fluctuation.

But how could you determine which diatoms lived in the past? Since diatoms are made of silica, they do not easily degrade over time when they die. Rather, they sink to the bottom of a lake and accumulate in the lake sediment. Scientists can extract the sediment and then determine what species were alive in the past. Based on the optimal environmental conditions that each species requires, scientists can reconstruct the environmental conditions of the past based on which diatoms are present in different segments of the lake core. Similar to an archeologist digging up dinosaur bones, they can draw some conclusions about the past environment. By examining lake sediment cores and understanding the ecology of a system, scientists can reconstruct the pH of these lakes back in time prior to recorded data.

Ivan and Kristin found a study from 1992 by Dixit *et al.* that reconstructed the past pH in Baby Lake in Ontario using extracted diatoms. Two key species were used in reconstructing the past pH: *Acidophilus Eunotia* (*acd*, acid loving) and *Acidobiontic Eunotia* (*acb*, living in acidic environments).

### Questions

- Based on the changes in abundance of two diatom species shown below (*Eunotia*), predict how you would expect the change in pH over time might appear. Sketch an image in the box to the right.



*Image credit:* Reprinted by permission from Springer Nature, *Water, Air, and Soil Pollution*, “Algal microfossils provide high temporal resolution of environmental trends,” by A.S. Dixit, S.S. Dixit, and J.P. Smol, ©1992.

*Questions*

12. Speculate on the long-term ecological impact if acid rain levels increase.
  
13. Do you think the government should regulate nitrogen and sulfate emissions from power plants and industry?  
Why or why not?
  
14. What actions could we take to decrease  $\text{SO}_2$  and  $\text{NO}_x$ ?



Kristin and Ivan resolved to core Bear Pond, identify the diatoms over time and determine if acid rain has always inflicted this ecosystem or if it is a one time, abnormal occurrence.

