Lake Michigan by the Numbers

Grades 6-12

- Interdisciplinary
  - » Math
  - » Chemistry
  - » Art
  - » Biology
  - » Science
  - » Reading and Writing
- Educator Driven
- NGSS Compliant

WRITTEN BY EDUCATORS
WRITTEN FOR EDUCATORS

Using real-time buoy data to teach about Lake Michigan conditions and current issues

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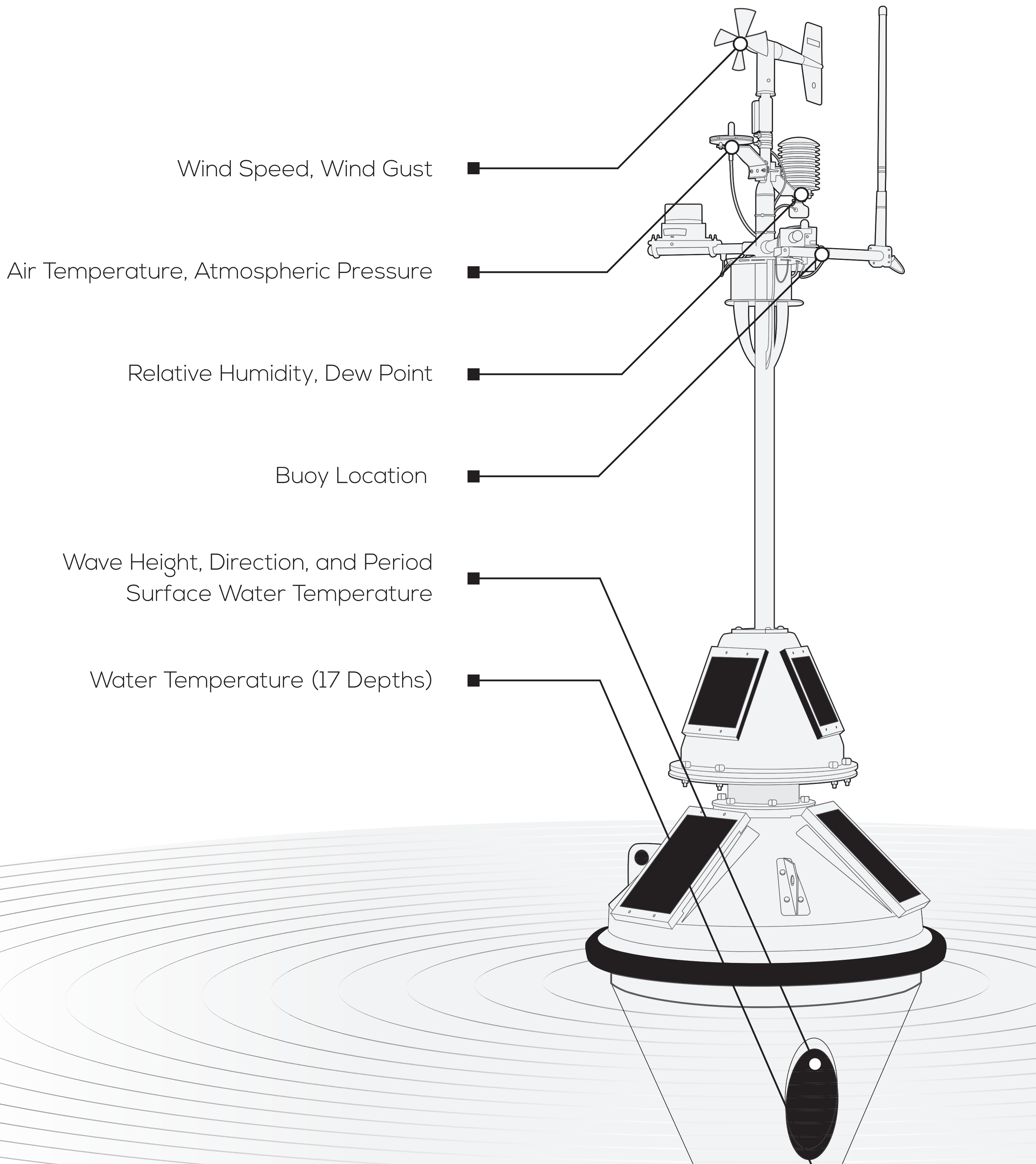
Wind Speed, Wind Gust
Air Temperature, Atmospheric Pressure
Relative Humidity, Dew Point
Buoy Location
Wave Height, Direction, and Period
Surface Water Temperature
Water Temperature (17 Depths)

Acknowledgments

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Introduction

Nearshore Lake Michigan Buoy
Michigan City, IN

Illinois-Indiana Sea Grant and the Purdue University School of Civil Engineering jointly operate a TIDAS 900 real-time monitoring buoy located four miles off Michigan City, IN. The exact location of the buoy is 41.75532N, 86.96847W, where the water depth is around 62′. The buoy is a little over 16′ in height – when deployed; about 10′ sits above the water surface and about 6.5′ below. The buoy weighs almost 500 pounds of which 150 pounds are the ballast tube, which provides stability. The buoy is fitted with a GPS unit to allow tracking of its location and is attached to a ton-weight concrete anchor on the floor of Lake Michigan. The anchor remains in the lake year-round while the buoy is deployed from approximately May through October each year.

The buoy is fitted with sensors to record:

- Air temperature
- Surface water temperature
- Water temperature at 17 depths
- Relative humidity
- Atmospheric pressure
- Wave height
- Wave direction
- Wave period
- Wind speed
- Wind gust
- Wind direction
- Solar radiation

Conditions are captured as they occur and transmitted every 10 minutes to several different websites.

The Michigan City buoy serves many audiences. For the National Weather Service, buoy data are used to forecast wave and weather conditions, observe current conditions, and revise forecasts based on how observations are changing (in some cases issuing small craft advisory warnings). Boaters, anglers, paddlers and surfers use the data to make decisions about whether or not to spend a day on the water. Charter fishermen use the data to make similar decisions, in addition to checking which locations will be good for fishing based on current wind, wave and temperature conditions.

Long-term data can be used to:

1) Develop prediction models
2) Fill gaps in other data sets
3) Relate historic conditions to future changes in Lake Michigan

Access Michigan City buoy data and more information at:
http://www.iiseagrant.org/buoy/

Lesson 1: Save Our Great Lakes

Using infographics to represent data, information and knowledge
By Deb Broom

Grade Level: 9-12

Lesson Time:
Five class days (one teacher led instruction day on infographics, one day to get familiarized with the website and three computer days to complete project)

Materials Required:
- Computer with Internet access

Nature of Science (NGSS) Standards:
NOS.2
NOS.3
NOS.4
NOS.11

Related Resources:
Piktochart: piktochart.com

Infogram: https://infogr.am

Summary

Infographics are graphic representations of information, data, or knowledge. They are great for presenting information quickly and clearly and are fast becoming an essential communication tool.

We live in a busy world, where people don't always have time to read pages of text in order to find needed information; lines of text will never engage readers the way that an image does. That is why infographics are great promotional tools for environmental campaigns. Unfortunately, it seems that gaining the public's attention about this very serious matter calls for more creative approaches.

Objectives

- Create an infographic using buoy data as well as other resources.
- Learn how to communicate a message through infographics.
- Learn about the Great Lakes and develop an understanding of buoy data.
- Show cause and effect drawing conclusions using buoy data and other resources.
- Explore creativity and multimedia skills.
- Learn the basics of using graphics software.

Introduction

With Earth Day just around the corner, why not launch your own "Save Our Great Lakes" project? Start a hypothetical environmental campaign and ask your class to create infographics to promote a deeper understanding of the Great Lakes and encourage greater environmental awareness.

As part of this campaign, high school students can use graphic design software— free on the Internet— to create colorful, interesting, and informative infographics that can be placed in parks, schools, and communities. The infographics will draw attention to the environmental issues that are threatening Lake Michigan as well as the other Great Lakes.

Direct students to one of the sites below for their project. I use Piktochart, which features user- friendly navigation and registration.

Piktochart: piktochart.com
Infogram: https://infogr.am

Lesson

Before your students can create the infographics, they will need to develop a better understanding of the Great Lakes and the environmental threats they face. Examine the problems, causes, possible solutions, and potentially disastrous effects to humanity if these issues are not addressed.

First, hold an open discussion with your class to find out what they already know about the Great Lakes and the role of buoys. Ask questions like: *What are the three basic things you know about the Great Lakes? How were they formed? Why should we protect our Great Lakes? How is using buoy data beneficial?*

Next, put students into groups of three or four and assign a Great Lake. Yes, you will have repeat groups since there are only five Great Lakes. Have students gather some general research on their lake, including basic information about geology, important facts and statistics, buoy information (www.ndbc.noaa.gov, www.greatlakesbuoys.org, www.iiseagrant.org), and recommendations on ways to get the world's attention about these freshwater treasures.

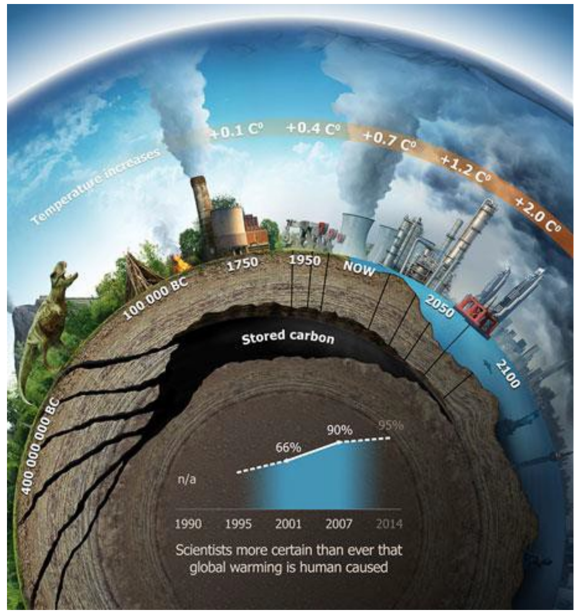
Once they've carried out their research, ask students to think about how they'd like to present this information to their target audience. Since infographics are often used as promotional tools, encourage your students to approach their project by thinking about what will be the most interesting, persuasive, enlightening, and effective way to present their lake to the public.

Because the topic of the Great Lakes is essentially about protecting and conserving, they may want their infographics to include eye-opening statistics and other related scientific data that will grab their audience's attention. Have them look at the way other infographics are designed. There are plenty of inspiring examples on the Internet. A teacher-led PowerPoint presentation on creating an infographic would be beneficial.

Creating a balanced color scheme throughout their infographic is also easy, thanks to the program's abilities to generate a palette of colors from any image. Plus students can create composite images by applying high-end effects to photos with the program's built-in photo-editing tools. Once they're finished, students can export their document as a PDF for professional printing or sharing online.

Examples

Source: USDA Natural Resources Conservation Service



Source: climasphere.org

Assessment

Students' grades should be based on their ability to:

- Present accurate information and comprehension of the subject matter.
- Find, select, and organize relevant information.
- Understand the underlying basics of their design.
- Match the content and language to their intended audience.

Lesson 2: Buoy, Oh Buoy!

How does differential heating affect the temperatures of the air and surface water?
By Laurie Littke and Carrie Sanidas

Summary
Students will discover how land, air, and water absorb energy differently. Students begin by performing a lab investigation where they observe and compare the temperatures of sand, water, and air as they heat and cool. After completing the lab, students will compare their results to buoy data. They will use air and surface water temperature buoy data that has been collected over the course of one buoy season. Students will create graphs of the data to compare and contrast how water and air absorb energy.

Grade Level: 6-8

Lesson Time:
A Day at the Beach, 2-3 days
Analyzing Buoy Data, 3-4 days

Materials Required:
- Heating Land and
- Water Lab Sheets
- Lab Supplies
- Buoy Data Table 1
- Buoy Data Table 2
- Analyzing Buoy Data
- Lab Sheet
- Calculator
- Graph Paper

Indiana State Science Standards:
6.1.7
6.4.3
7.1.4
8.2.1

Great Lakes Literacy:
GLLP 3

Related Resources:
National Buoy Data Center
http://www.ndbc.noaa.gov/maps/WestGL.shtml

Objectives
- Perform an experiment to understand differential heating in sand, air, and water.
- Evaluate buoy data to observe the result of differential heating.
- Use buoy data to create line and bar graphs.
- Use buoy data for statistical analysis.

Vocabulary
- **Differential heating**– the process by which different materials, such as air and water, heat up at different rates.
- **Heat**– also known as thermal energy is the vibration of atoms and molecules within a substance. The more a substance is heated, the more quickly its atoms and molecules vibrate.
- **Heat transfer**– the movement of heat (thermal energy) from one substance or object to another.
- **Lake effect**– large bodies of water, like the Great Lakes, have a noticeable impact on the temperature and weather of surrounding areas. Lake effects commonly include a buffering of temperature and more frequent precipitation, i.e. lake-effect snow.
- **Mean**– the mathematical average of a set of numbers calculated by adding up all numbers in a data set and then dividing the sum by the quantity of numbers in the data set. For example, 3+7+8=18; 18÷3=6. The mean of 3, 7, and 8 is 6.
- **Radiation**– a form of kinetic energy that comes from the sun and travels as waves through space and air. Radiation from the sun can be visible like light, or invisible like heat, X-rays, and radio waves.
- **Range**– the difference between the largest number and smallest number in a data set.
- **Temperature**– a measure of the amount of heat (thermal energy) in the air or substance. Using thermometers, temperature is most often recorded in units of degrees Fahrenheit or Celsius.

Introduction
Students are introduced to the topic of differential heating by reading a short story about two friends, Jack and Jill, who go to the beach. As students perform the activities, they will be asked to explain to Jack and Jill the phenomena that the friends experienced.

Data Activity
A. Heating Land and Water Lab Teacher Preparation

Preparation
For each group, you will need:
- Suggested group size 3-4 students
- 3 containers with lids – clear, ½ pound deli containers work well
- Knife (for teacher to cut slit in container lids)
- 3 Celsius thermometers (metal-backed is recommended)
- 1 timer/stopwatch (or one for the class) See note about timekeeping in Lab step 7.
- Lab sheets titled "Heating Sand, Water, and Air Lab"
- Graph paper
- 3 colored pencils/markers
- Dry sand
- Room temperature water
- Graduated cylinder or ½ cup (120 ml) measuring cup
- Outdoor location that receives direct sunlight and a nearby shady area or lamp
- Sheet of newspaper

1. Copy lab sheets for each student.
2. Make a small slit in each lid, just large enough for the thermometer to fit through.
3. Each group will need 3 containers with thermometers. The three containers will hold:
    - 120 ml sand (1/2 cup)
    - 120 ml room temperature water (1/2 cup)
    - Air

4. Set up the 3 containers as pictured right.
5. If it is a sunny day, students will go outside to perform the lab. Students should place their containers on the newspaper to limit the heat exchange between the container and the ground.
   If it is overcast, plan to have a lamp for each group. To remain consistent, use the same size light bulb and keep the distance from the containers the same.

Lab
1. Review that heat is a form of energy and an element of weather. Use the following questions to begin the lab:
    - When we look at a weather forecast and observe the temperature, what are we finding the temperature of?
      (The temperature of the air in a given location)
    - What time of day is air at its hottest?
      (During the afternoon)
    - What time of day is air at its coldest?
      (In the morning, just before the sun rises)
    - What is the energy source that heats the Earth and air?
      (The sun)
    - If we wanted to find the warmest outside area around our school, where would we go?

(A sunny area out of the wind)

- How do you think the type of surface covering the land affects air temperature? *(Answers will vary; this is the lead into the lab.)*

2. Explain to students that today they are going to investigate what happens when sand, water, and air are exposed to a light/heat energy source. They will observe and measure the temperature changes in these three materials as they are heated and cooled.
3. Students should review the materials list and procedure before beginning the lab.
4. Ask students to write their predictions that compare the heating and cooling for the sand, water, and air.
5. Each group should inventory their lab supplies. Have students measure and set up the containers as directed with each material. They should carefully put the lids on the containers.
6. Thermometers should be carefully inserted into lids, with the bulbs below the surface of the sand and water– away from sides of the container to ensure you are taking temperature of the material and not the container.
7. Students will be recording the temperatures every 2 minutes for 28 minutes. (Each group can keep their own time or you/a student can be the timekeeper and call out the 2-minute intervals. Be sure to run a continuous stopwatch.)
8. Record the initial temperatures in the 0 minute column on the data table for each material.
9. If students are going outside, carry the supplies to the designated location and set the containers on the newspaper. The newspapers should be folded several times so it insulates the containers. If students remain inside, turn on the lights and start the watches at the same time.
10. Students will measure and record the temperatures for 14 minutes. After 14 minutes, students either turn off their lamps or move their containers to a shady location. They will continue to measure and record the temperatures as the substances release heat. If using the same containers for multiple classes, remove the lids between classes to allow the materials to cool.
11. Students will create a triple-line graph of the results.

Discussion and Application Questions for “A Day at the Beach”

1. Which material(s) heated up the most in the 14 minutes? The least in 14 minutes?
2. Which material(s) cooled the most in 14 minutes? The least in 14 minutes?
3. Did all 3 materials receive the same amount of solar energy/light?
4. Why do you think the materials heated differently? Cooled differently?
5. What properties of the sand, water, and air may have caused them to heat up or cool down at different rates?
   Types of answers that you will receive include:
   - *The sand heats most, while the water heats least.*
   - *The sand cools most, while the water cools least.*
   - *All 3 materials received the same amount of energy/light.*
   - *Materials heat differently because they are different colors.*
   - *Water heats slowly because the molecules don’t move as fast when they absorb energy.*
   - *The distance between particles of solid (sand), liquid (water) and gas (air) affect the heating and cooling.*
   - *Air isn’t as dense as the other materials, so it doesn’t take as long to heat up.*
6. If sand, water, and air all received the same amount of light energy, how can you explain the differences in temperature?

Tell students:

Water has an important property. It takes five times more energy to raise an amount of water one degree Celsius than it does to raise the same amount of sand one degree. When the same amount of heat energy is absorbed equally by all materials, the temperatures of the sand goes up faster than water.

If a kilogram of water and a kilogram of sand absorb an equal amount of solar energy, the temperature of the sand will be much higher than the temperature of the water. The water doesn't get as hot, but is has absorbed the same amount of heat energy.

7. The sun heated the earth materials that were in the containers. How did it do that? How did energy get from the sun to the sand, water, and air?

   Allow the students to answer this question.

   Explain to the students:

   Energy that comes from the sun is known as radiant energy. Radiant energy travels as waves through space and air. Radiation from the sun can be visible like light, or invisible, like heat, X-rays, and radio waves.

   If students aren't familiar with the electromagnetic spectrum, please provide a graphic to help them understand the types of radiant energy.

   When radiant energy strikes an atom or molecule, like our air, sand, or water molecules, the molecules gain more energy and begin to move faster or vibrate more. We say that the molecule has absorbed the radiant energy. The radiant energy has been transferred from the sun to the earth materials.

   The motion of molecules is heat. The more motion there is in the molecules of matter, the hotter it is.

   Different materials heat up at different rates. This is called differential heating. Differential heating accounts for the differences in the temperatures of the water, air, and sand in our investigation, even though they were exposed to the same amount of light.

   Water in lakes and oceans can store more heat than land masses, even though the temperature of the water may be lower.

8. Students should write a note to Jack and Jill. They should answer the problem question, "Why are the sand, air, and water different temperatures?" Students need to include evidence from the investigation to support their answer. Their answer should also include the following terms: heat, temperature, energy, and differential heating.

B. Analyzing Buoy Data

Preparation
For each student, you will need:

- Analyzing Buoy Data lab sheet
- 1 Buoy Data Table 1* (contains data for a single day)
- 1 Buoy Data Table 2** (contains data for a season)
- 3 pieces of graph paper
- Colored pencils/markers
- Calculator

Lab

1. Review the results of “A Day at the Beach” with students.
2. Explain that there is a buoy anchored in Lake Michigan, 3 miles off of the beach. This buoy has instruments on it that measure many weather factors. These factors include the air temperature, water temperature, wind speed and direction, wind gusts, wave direction and height, and dew point.
3. Before distributing Buoy Data Table 1, ask students to write a prediction statement about how a line graph of the temperatures of the water and air over a 24-hour period will look. Distribute the Analyzing Buoy Data student sheet.
4. Discuss questions/answers that the students have worked on for part 1.
5. Students should predict air and surface water temperatures for a buoy season, from June to October.
6. Students should then review Buoy Data Table 2.
7. Ask students to calculate the mathematic range and average (mean) temperatures for both air and surface water over the buoy season. Answers should be recorded in their data table for question 2.
8. Students should share and discuss their mean values that they have calculated and attempt to explain the differences.
9. Students will create a double-line graph of the time versus temperatures of both air and surface water for the buoy season.
10. Students should calculate the mean air and water temperatures for the 2014 buoy season for each month and record their calculations in the data table for question 5.
11. Students will create a double-bar graph of the means recorded in question 5.
12. Students should then answer questions 4-12 on the Analyzing Buoy Data Student Sheet.

* If students have difficulty rounding, create a data table with numbers to the place value that they are able to comprehend.

**Time is measured using the 24-hour clock. Teach students how to use the 24-hour clock or modify the data table for a 12-hour clock time frame.

Discussion and Application Questions for "Analyzing Buoy Data"
Part 1

1. How do the air and water temperatures compare?
   Students should share the similarities in the two sets of temperatures.
2. How do the air and water temperatures contrast?
   Students should share the differences in the two sets of temperatures.
3. How would you describe the graph using the terms "differential heating" and "energy?" The water heats and cools much slower than the air because of differential heating. The water went from 22.26 °C, down to 22.12 °C, and back up as high as 22.36 °C in the 24- hour period. The air started at 25.59 °C, rose to 25.96 °C, then returned to as low as
   21.37 °C.

Part 2

4. Students will review Buoy Data Table 2. They should notice that the air temperature ranged from 13.3 °C in June, to as high as 26.0 °C in September, and then dropped back to 13.3 °C in October just before the buoy was removed. The water temperature ranged from 18.2 °C in June, to 23.3 °C in September, with a final temperature of 17.3 °C in October.

	Air Temperature (degrees C)	**Water Temperature (degrees C)**
Range	13.3-26.0 12.7	12.9-23.3 7.4
Average (mean)	21.1	20.5

5. The students should calculate the following means from Buoy Data Table 2:

Month	**Air Temperature (degrees C)**	**Water Temperature (degrees C)**
June	20.28	18.98
July	22.0	21.53
August	23.4	21.94
September	20.18	20.2

6. The double-bar graph should illustrate the differences in the means.*
7. The students should predict that as the year progresses, the water temperatures will decrease slowly while the air temperatures drop at a faster rate.
8. The predictions for air and water temperatures in December should be based upon extending the lines in their first double-line graph of data from Buoy Data Table 1. Assume that water will not be colder than 0°C and won't turn into ice.
9. The note to Jack and Jill should detail the buoy and the types of data that are collected, as well as including specific examples of temperatures collected over the buoy season.

Extensions
Use a full day's data that can be obtained from one of several websites (See Appendix A; www.ndbc.noaa.gov, www.greatlakesbuoys.org, www.iiseagrant.org).

Ask each student to graph a full day's air temperature and/or water temperature, including water temperature at different depths. Use a spreadsheet program to graph data. Students can arrange their graphs in chronological order in the classroom. Students can create double-line graphs comparing other data sets.
Suggested comparisons are:

- Time vs. Temperature and Air Pressure
- Time vs. Air Temperature and Wind Speed
- Time vs. Wind and Wave Height

Rather than take measurements every 2 minutes for 28 minutes, take measurements once per hour for a whole day, or at the same time every day for a whole week. Consider factors like weather that day that may be influencing the temperature changes.

* When making the double bar graph in part 2, also calculate a measure of error around the mean (standard deviation, standard error, or maximum/minimum values). Talk about which months have wider/narrower error bars and how the error bars overlap.

A Day at the Beach **Name** ________________________________

Background
Jack and Jill, along with their mother, went to a Lake Michigan beach one sunny holiday weekend. As they walked toward the lake, Jack and Jill took off their shoes. "Ouch! This sand is hot!" exclaimed Jack. "Yes, my feet are getting burned!" cried Jill. Their mother said, "Put your feet into the lake, that will cool them off."

Once they put their feet in the water, the kids wondered why the lake is so much cooler than the sand, given that the sand, the water, and the surrounding air are in the same location.

Problem
Why are the sand, air, and water different temperatures?

Prediction
Read the Materials and Procedure. Predict which material will heat the most and least. Also predict how the temperatures in the materials will be affected when the lamp is turned off or the materials are moved into the shade. Make sure to include "because" explanations in your predictions.

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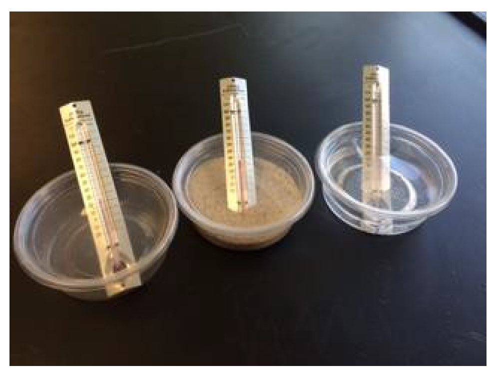
Materials
- 3 containers with lids
- 3 thermometers
- 1 timer/stopwatch
- Dry sand
- Room temperature water
- Graduated cylinder or ½ cup (120 ml) measuring cup
- Sheet of newspaper
- Graph paper
- Colored pencils/markers



Procedure
1. Measure 120 ml of sand into a container.
2. Measure 120 ml of water into a container.
3. The third container will have only air in it.
4. Carefully put the lid on each container.
5. With the bulb side down, gently push the thermometer into the slit in the lid. Make sure the bulb of the thermometer is completely covered by the sand and the water and is not touching the sides of the container.
6. Measure and record the temperature in the sand, water, and air on your data chart. This is the 0 minute temperature.

7. You will use either lamp light or sunlight as a light source for your materials. Follow teacher instructions.
8. When you are instructed, start timing your materials as they are exposed to light. Every 2 minutes, you will measure and record the temperature.
9. After 14 minutes, you turn off the lamp or move your materials to shade. You will continue to run the stopwatch as you measure and record the temperature for each material every 2 minutes for 14 more minutes.
10. Follow clean up instructions.
11. Using 3 different colored pencils/markers, create a time vs. temperature line graph to demonstrate the temperatures of the sand, water, and air over 28 minutes. Use a different color for each substance and make sure to include a key on your graph.

Data Table

Temperatures of Earth Materials as They Are Heated and Cooled

Earth Material Temperature ℃

Time (minute	SAND	WATER	AIR
0			
2			
4			
6			
8			
10			
12			
14			
TURN LAMP OFF	XXXXXXXXXXXX	XXXXXXXXXXXXXXXXX	XXXXXXXXXXXXXXXXX
16			
18			
20			
22			
24			
26			
28			

Analyzing Buoy Data **Name**_____________________________________

Buoy 3 miles off Washington Park Harbor in Michigan City, IN.

Background

As Jack and Jill are enjoying their day at the beach, there is a buoy anchored 3 miles off shore that is collecting many types of weather and water data. This buoy is measuring and transmitting information about wind, wind speed, air pressure, and even the air and surface water temperatures. The information that is being recorded at the buoy can be used to help explain to Jack and Jill the differences in the air and water temperatures at the beach.

Problem

How do the air and surface water temperatures in Lake Michigan compare and contrast over 24 hours (1 day)? How do they compare and contrast and over a buoy season in Lake Michigan?

PART 1 – examining changes over 24 hours (1 day)

Prediction

You will be given the hourly air and water temperatures from the buoy. When you create a graph, how do you expect the air and water temperatures to change over 24 hours? Use a "because…" statement in your prediction.

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Materials

- Buoy Data Table 1
- Graph paper
- 2 colored pencils/markers

Procedure

1. Create a double-line graph of the data in Buoy Data Table 1.
2. Put the hour on the x-axis. Note that the time is the 24-hour clock.
3. Put the temperature in degrees Celsius on the y-axis.
4. Create a key that indicates which colors will represent air and water temperatures.
5. Graph each data set.
6. Create a title for your graph.

PART 2 – examining changes over 1 season (June through October)

Prediction

In this part of the activity, you will analyze data collected over a whole buoy season. The measurements were taken from June 6 to October 3, 2014. Predict how you think the air and water temperatures will change over the months of June to October. Include a "because" statement in your prediction.

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Materials

- Buoy Data Table 2
- Calculator
- 2 sheets of graph paper
- 2 colored pencils/markers

Procedure

1. Review the air and water temperatures in Buoy Data Table 2.
2. What patterns do you notice?
3. Calculate the following:

	Air Temperature (degrees C)	**Water Temperature (degrees C)**
Range		
Average (mean)		

4. Explain the range for the air temperature and the water temperature.

5. Compare the average water and air temperatures.

6. Create a double-line graph of the measurements in Buoy Data Table 2.
   - Label the x-axis date.
   - Label the y-axis temperature (in degrees C)
   - Create a key that indicates the colors that will represent air and water temperatures.
   - Graph each data set.
   - Give the graph an appropriate title.

7. Complete the data table below, calculating the averages for each month:

Mean Air and Water Temperatures for 2014 Buoy Season

Month	Air Temperature (degrees C)	Water Temperature (degrees C)
June		
July		
August		
September		

8. Create a double-bar graph of the means that you calculated in the table above.
    1. Label the x-axis month.
    2. Label the y-axis temperature (in degrees C).
    3. Create a key to indicate air temperature and water temperature.
    4. Graph your mean temperatures.
    5. Give the graph an appropriate title.

9. Examine the double-bar graph. Explain how the lake and air received the same amount energy, yet their means are different.

10. Using your graphs, predict the air temperature if the buoy remained in Lake Michigan until the first of December.

11. Using your graphs, predict the water temperature if the buoy remained in Lake Michigan until the first of December.

12. Write another note to Jack and Jill. Use the buoy data to explain differential heating at Lake Michigan beaches. In your explanation, include the important vocabulary terms.

Buoy Data Table 1
24 Hour
Temperatures

TIMESTAMP	Air Temperature	Water Temperature
TS	Deg. C	Deg. C
	Avg.	Avg.
9/5/2014 0:00	25.59	22.26
9/5/2014 1:00	25.69	22.24
9/5/2014 2:00	25.54	22.21
9/5/2014 3:00	25.19	22.2
9/5/2014 4:00	24.75	22.18
9/5/2014 5:00	24.44	22.16
9/5/2014 6:00	24.17	22.14
9/5/2014 7:00	24.05	22.12
9/5/2014 8:00	24.22	22.13
9/5/2014 9:00	24.58	22.17
9/5/2014 10:00	24.62	22.24
9/5/2014 11:00	25.4	22.36
9/5/2014 12:00	25.21	22.54
9/5/2014 13:00	25.58	22.67
9/5/2014 14:00	24.77	22.91
9/5/2014 15:00	24.86	23.37
9/5/2014 16:00	25.96	23.3
9/5/2014 17:00	22.57	22.46
9/5/2014 18:00	21.36	22.36
9/5/2014 19:00	21.26	22.33
9/5/2014 20:00	21.84	22.33
9/5/2014 21:00	21.51	22.34
9/5/2014 22:00	21.11	22.36
9/5/2014 23:00	21.37	22.36

Buoy Data Table 2
Weekly
Temperatures

6/6/2014 16:00	18.5	18.2
6/13/2014 16:00	14.7	15.9
6/20/2014 16:00	22	21.3
6/27/2014 16:00	25.9	20.5
7/4/2014 16:00	20.2	21
7/11/2014 16:00	23.1	22.8
7/18/2014 16:00	23.4	22.3
7/25/2014 16:00	21.3	20
8/1/2014 16:00	20.7	20.9
8/8/2014 16:00	25.3	22.6
8/15/2014 16:00	20.7	21.7
8/22/2014 16:00	25.4	22.5
8/29/2014 16:00	24.9	22
9/5/2014 16:00	26	23.3
9/12/2014 16:00	14.5	20
9/19/2014 16:00	21	18.5
9/26/2014 16:00	19.2	19
10/3/2014 16:00	13.3	17.3

Lesson 3: A Blue Day for the Karner Blue Butterfly

Could Lake Michigan water temperatures have an effect on butterfly populations?
By Eric March

Summary

In this exercise, students will use historical buoy data to construct a graph of the average springtime water temperature of select Lake Michigan locations. They will then plot this data against Karner Blue butterfly population counts at Indiana Dunes National Lakeshore (also student-constructed). Students should be able to accept or reject the hypothesis that warmer water temperatures influenced the Karner Blue population decline.

Grade Level: 8-9

Lesson Time:
Two 45-minute classes

Materials Required:
- Computer with Internet access
- Graph paper
- Or computer software capable of making a graph

Indiana State Science Standards:
B.4.2
B.4.4

Next Generation Science Standards:
HS-LS2-2
HS-LS2-6
HS-LS2-7

Great Lakes Literacy:
GLLP 3

Objectives

- Construct graphs based on Internet research of buoy data.
- Construct graphs based on provided Karner Blue butterfly count data.
- Interpret their graphs.
- Synthesize information from both graphs to accept or reject a hypothesis related to the decline in the Karner Blue population.

Vocabulary

- **Climate**– the prevailing or average weather conditions of a place, as determined by the temperature and meteorological changes over a period of years.
- **Correlation**–any of a broad class of statistical relationships involving dependence.
- **Data set**– facts or figures to be processed; evidence, records, statistics, etc.
- **Extrapolate –** to arrive at conclusions or results by hypothesizing from known facts or observations.
- **Graph**– a diagram showing the relationships between two or more variables.
- **Interpret**– to translate or explain what something means; to analyze graphs.

Introduction

The Karner Blue butterfly (*Lycaeides Melissa samuelis)* is a diminutive butterfly with a wingspan of about one inch that lives in the northern U.S. and southern Canada. Its habitat range has shrunk to the states around the Great Lakes, with Michigan and Wisconsin supporting the largest number of these butterflies. However, even these states support only small populations of Karner Blue butterflies, which are at risk of local extinction. Habitat loss has been named as the primary cause for the decline of the butterfly, but climate change is also a possible reason.

This class investigation could be structured as a mini case study, with students in place of climate researchers.

www.albanypinebush.org

The teacher should explain what a buoy is and why they are used in the lake. Information about real-time monitoring buoys can be found at http://iiseagrant.org/buoy/. The teacher should also make the distinction between climate and weather, with the former having impacts over the long term and potentially being a driving force behind large-scale changes to ecosystems. A discussion could be had about the specific heat capacity of water and how it influences local weather and climate.

From the National Snow and Ice Center website: (https://nsidc.org/cryosphere/arctic-meteorology/climate_vs_weather.html)

"Weather is the day-to-day state of the atmosphere, and its short-term variation in minutes to weeks. People generally think of weather as the combination of temperature, humidity, precipitation, cloudiness, visibility, and wind. We talk about changes in weather in terms of the near future: 'How hot is it right now?' 'What will it be like today?' and 'Will we get a snowstorm this week?'

Climate is the weather of a place averaged over a period of time, often 30 years [or more]. Climate information includes the statistical weather information that tells us about the normal weather, as well as the range of weather extremes for a location.

We talk about climate change in terms of years, decades, and centuries. Scientists study climate to look for trends or cycles of variability, such as the changes in wind patterns, ocean surface temperatures and precipitation over the equatorial Pacific that result in El Niño and La Niña, and also to place cycles or other phenomena into the bigger picture of possible longer term or more permanent climate changes."

Students should be instructed to gather data, and graph both sets on the same graph. This will allow for easier interpretation and analysis. Students should analyze the graph and see if there is a correlation between Lake Michigan temperature and a decrease in the Karner Blue population.

Data Activity

Students should use data from a Lake Michigan buoy. Historical data can be downloaded from http://www.ndbc.noaa.gov, greatlakesbuoys.org or iiseagrant.org. (See Appendix A.) The buoy in the center of the southern basin of Lake Michigan (45007) may be most appropriate for this lesson.

A. Students should be instructed to make a data table for the date range of 1994–2010, as this correlates to population data provided for the butterflies. Students can use an advanced search to only get data that they need (in this case, temperature on a certain date over a number of years.) Students should choose a date in the spring, as well as the late summer or early fall. This timing coincides with the Karner Blue butterflies' two egg-laying times per year. In the population charts below, Brood 1 corresponds to the spring brood, while Brood 2 corresponds to the late summer brood.

B. Once the students have constructed the data table for their buoy, they should use graph paper or a computer to generate a graph, either a bar or line graph would be appropriate. They can use different colors to represent the different times of the year.

C. On the same graph, students should use a different color to graph the Karner Blue butterfly population from the provided data tables. Only one data table should be used, but a few are provided so students' graphs will be different. Students will now be able to analyze the graphs in order to determine if there was a correlation between average lake temperature and a decrease in the Karner Blue population.

Discussion and Application Questions

1. What was the peak population for the Karner Blue butterflies in your area? In what year did it occur?
2. What is the overall trend in the butterfly population over time?
3. What is the overall trend in Lake Michigan water temperature over the same period of time?
4. Based on your graphs, do you think that Lake Michigan warming can be a factor in the decline of the Karner Blue butterfly population? Why or why not?

Extensions

- Students could be instructed to calculate the slope of the lines for the data sets that they have constructed.
- Students could compare the long-term temperatures from the offshore buoys (45007, 45002) to recent temperatures in the nearshore zone (45013, 45174, 45170, 45026, 45168, 45029, 45161, 45024) and discuss implications of temperatures in different parts of the lake.
- Students could get average temperature data from another source (e.g., weather stations on land http://www.glerl.noaa.gov/metdata/) to compare with the over-water buoy data.
- Students could link temperature data to other species, for example fish species living in the lake.

Karner Blue population data, courtesy National Park Service, Indiana Dunes National Lakeshore:

Year	No. of Karner blues observed	Total No. of Sites
1994	0	0
1995	508	3
1996	278	5
1997	439	5
1998	712	5
1999	532	5
2000	229	5
2001	280	5
2002	173	5
2003	149	5
2004	133	5
2005	228	5
2006	122	5
2007	65	5
2008	115	5
2009	94	5
2010	53	5

Year	No. of Karner blues observed	Total No. of Sites
1994	392	2
1995	488	4
1996	714	5
1997	1379	5
1998	1447	5
1999	726	5
2000	493	5
2001	467	5
2002	414	5
2003	278	5
2004	360	5
2005	487	5
2006	267	5
2007	186	5
2008	125	5
2009	68	5
2010	225	5

Lesson 4: Michigan City Buoy and Trail Creek Hydrolab Data

Comparing Water Quality Data to Predict Fish Species
By Stephanie Dege

Grade Level: 9

Lesson Time:
1 Full-day Field Trip 3 Class Periods

Materials Required:
- Hydrolab
- Smart Phones
- Laptops
- Data Sheets

Indiana State Science Standards:
B.3.4
B.3.5
B.4.1
B.4.2
B.4.3

Great Lakes Literacy:
GLLP 5

Related Resources:
www.ndbc.noaa.gov/

Hydrolab Workbook

Summary
Students will take part in a field trip to the Michigan City Port Authority Marina on Lake Michigan. Here they will access real-time data from the buoy website using their phones, and then record it on a data sheet. At this time, we will also have the Hydrolab on loan, and students will use it to record data from the Hydrolab on their data sheet as well. Students can compare buoy data from farther out in the lake vs. data inside the marina. The next portion of the field trip will be held at Trail Creek, a Lake Michigan tributary. Students will again use the Hydrolab and record data on their data sheet. Students will compare data from the buoy, the marina, and Trail Creek and look for similarities and differences in the readings. When students return to class, they will engage in an extension activity of researching different native fish species and the water conditions they require (especially temperature). Students will then predict in which of these three areas (the waters of the marina, offshore Lake Michigan, and/or Trail Creek) the respective species would likely be found.

Objectives
- Students will understand how water conditions vary in different areas of Lake Michigan and in a tributary of Lake Michigan.
- Students will understand that different species of fish have different habitat requirements.
- Students will understand that fish species will live in a habitat that most closely fits their water temperature and quality requirements.

Vocabulary
Relevant for the use of the Hydrolab as well as buoy data:
- **Barometric pressure**– the pressure exerted by the weight of the atmosphere.
- **Buoy**– an anchored float used for a variety of purposes such as serving as navigational markers. A scientific buoy houses sensors that collect information such as water temperature, wave height and barometric pressure.
- **Hydrolab**– scientific monitoring equipment that records water quality parameters. The Hydrolab DS5 datasonde contains seven sensors that measure chlorophyll a, conductivity, dissolved oxygen, pH, temperature, and turbidity.
- **Chlorophyll *a***– the green pigment in plants that helps plants change light into food (i.e., for photosynthesis). Chlorophyll a is measured as the number of micrograms per one liter (µg Chl a/L) of water.
- **Conductivity**– water's ability to conduct an electrical current. In distilled water the current does not have a medium in which to flow easily, but when ions (from dissolved salts) are present in water the electrical current can easily pass through. Electrical conductivity (EC) is measured in microsiemens per centimeter (µS/cm).

- **Dissolved oxygen**– (DO) a measure of the relative amount of oxygen that is dissolved within water. Standard units are milligrams per liter (mg/l) or parts per million (ppm).
- **pH**– shows how acidic or basic a water body is. The amount of hydrogen ion activity in water determines the level of pH on a scale from 0-14.
- **Turbidity**– often used as a proxy for water clarity, turbidity measures the intensity of light scattered by particles in the water sample at 90° incident to a light source. Reported in units called Nephelometric Turbidity Units or NTUs.

- **Species of fish likely to be found near Michigan City and Trail Creek (see also Appendix C):**
  - Alewife
  - Bloater
  - Bluegill
  - Chinook salmon
  - Coho salmon
  - Freshwater drum
  - Lake trout
  - Rainbow smelt
  - Rock bass
  - Round goby
  - Spottail shiner
  - White sucker
  - Yellow perch
- **Tributary**– a stream or river that flows into a larger stream or other body of water.
- **Spawn**– the deposit of eggs by fishes in order to reproduce.

Introduction
Fishing is an important industry as well as pastime for people who use Lake Michigan. Understanding how different aspects of water quality affect the fish in the lake is essential. This allows organizations and individuals to understand the impact that humans have on the lake and the fish that live in it.

Different species of fish can be found in different habitats in the lake. Knowing the water and habitat preferences of each species allows people to find the fish species they are looking for. It also allows people to understand the health of the lake. For example, if a habitat that normally has ample fish numbers is suddenly found to be bare, that would be a warning sign that there is something wrong. People can then look at factors that cause changes to habitats, such as changes in water temperature, dissolved oxygen, invasive species, chlorophyll, pH, etc.

The water quality in the lake affects the fish that live in it, but the water in Lake Michigan tributaries is also important. Many of the fish in Lake Michigan swim up into small rivers and creeks to spawn. This is where young fish will spend years growing and developing until they are large and strong enough to survive in Lake Michigan. Understanding the habitats and water requirements that these young fish need is important to keeping a healthy population of fish in Lake Michigan.

During this multi-day field trip and activity, students will collect data from both Lake Michigan and Trail Creek. The data will be collected from the Illinois-Indiana Sea Grant buoy in the nearshore waters of Michigan City as well as by using the Hydrolab. Students will then take this data and research fish species in Lake Michigan and make predictions about where each fish species could be found (the waters of the Michigan City Port Authority Marina, offshore Lake Michigan, and/or Trail Creek).

Data Activity

A. When arriving at Lake Michigan near Washington Park, Michigan City, students will use their smart phones to access the Michigan City buoy data real-time information at http://www.ndbc.noaa.gov/. Students will record data on their data sheet.

B. Students will use the Hydrolab to record water data from water in the Michigan City marina.

C. Students will then travel to Trail Creek to record water data using the Hydrolab.

D. When back in class, students will discuss and compare data from all three sites. Students will then use the internet to search water requirements for each of the fish species found in the vocabulary section above. They will be required to search for water requirements for both young and adult fish. They will record this information on a sheet provided by the teacher.

E. Students will complete the activity by using data from each of the three visited sites along with their research information on fish species in order to predict which of the three sites the fish would likely be found (they may be found at more than one site; students will need to indicate whether they are found at a site during juvenile or adult years).

Discussion and Application Questions

1. Which data were similar between the three sites? Why do you think this is?
2. Which data were different? Why do you think this is?
3. Why is it important to understand how the water affects the fish population of Lake Michigan?
4. What do you think are the top three things that you need to know about the water if you are trying to determine if an area would be a good fish habitat?
5. Why it is important to know what is happening in Trail Creek?
6. Why are tributaries so important to Lake Michigan's fish?

Extensions

- Research the main invasive fish species of Lake Michigan to find out their water requirements. Using the water data, determine why these species have been able to survive in the waters of Lake Michigan.
- Examine temperature data trends at the surface of the lake water, the bottom of the lake, and local tributaries. Discuss implications for where fish might choose to reside.

Other Resources

Indiana Department of Natural Resources: http://www.in.gov/dnr/
U.S. Fish and Wildlife Service: http://www.fws.gov/
Trail Creek Watershed: http://tcwatershed.org/
LaPorte County Soil and Water Conservation District: http://www.laporteswcd.com/

Lesson 5: Adopt a Buoy

Exploring Graphing Using Buoy Data
By Jennifer Smith

Grade Level: 8

Lesson Time:
One class (40 minutes)

Materials Required:
- Adopt a Buoy Worksheet
- Internet Access

NGSS Science and Engineering Practices:
Analyzing & Interpreting Data
Engaging in Argument from Data

NGSS Crosscutting Concept:
Cause and Effect
NGSS DCI MS-ESS2

Great Lakes Literacy:
GLLP 1
GLLP 3

Summary

In this lesson, students will review their graphing skills as they use self-selected buoy data to create a data table and a graph. Students will also analyze the data they have collected by proposing a possible explanation for the change or lack of change in the data observed. This lesson has been designed for use by students who do not have experience with buoys.

Objectives

- Students will create an appropriate data table using buoy data.
- Students will create an appropriate graph using buoy data.
- Students will make inferences based on observed buoy data.

Vocabulary

- **Data table**– chart used to record observations in an organized manner
- **Data set**– collection of observed information
- **Pie chart**– graph used to display percentages of data
- **Line graph**– graph used to display how one variable changes in response to another variable over time
- **Bar graph**– graph used to display distinct sets of data
- **Inference**– logical explanation or interpretation of an observation
- **Observation**– information gathered about a topic or experience; must be accurate and factual
- **Buoy**– an anchored float used for a variety of purposes such as serving as navigational markers. A scientific buoy houses sensors that collect information such as water temperature, wave height and barometric pressure.

Introduction

To begin the lesson, the teacher asks students to describe a buoy and what it can be used for. After providing sufficient wait time, the teacher calls on students to share their responses with the class. As students share their ideas, the teacher reaffirms correct responses and redirects responses that are not accurate.

The teacher summarizes the introduction by showing students pictures of buoys and reviewing some of their functions. The following website can be helpful in demonstrating this information to students: http://www.boaterlicences.com/online_course_buoys.php.

The teacher then introduces information regarding the NOAA buoys on Lake Michigan by first reviewing information about bodies of fresh water (GLLP 1). The teacher will use GLLPs 1A, 1B, and 1C in a review of information about the Great Lakes. The teacher will also review the manner in which the Great Lakes impact local weather conditions and affect weather and climate (GLLP 3).

Next, the teacher explains a graphing activity in which the students will review data collected by a buoy on Lake Michigan to make data tables and graphs and then develop inferences based upon an analysis of their graphs.

Data Activity
The teacher directs the students to the NOAA website – http://www.ndbc.noaa.gov and explains the website features, including that lake buoys are represented by red, orange, and yellow diamonds.

The teacher should ensure that students choose a buoy (typically these have a 5 digit station ID and there will be a "water depth" in the description) and not an on-land weather station (typically these have letters in their station ID). Buoys in Lake Michigan include stations 45007, 45002 (offshore) and 45013, 45174, 45170, 45026, 45168, 45029, 45161, 45024 (nearshore).

The teacher explains that the students will be selecting one of the diamonds on the NDBC to "adopt" and report about.

The teacher reviews the Adopt a Buoy worksheet with students; and students complete the following activities for their adopted buoys:

A. As students prepare to create data tables and graphs for their buoys, the teacher leads a brief review of data tables as well as line, bar, and pie graphs, to ensure that students are aware of the best type of graph to use to display their data.

B. Students begin by selecting a graph that has already been created for their buoy. After selecting the graph, students observe changes in the graph and then write a paragraph describing those changes. Students will also make inferences about weather patterns in the area and the causes of those changes. For instance, an easy change to describe would be the lower temperature in the evening hours as the sun is no longer heating the lake. (NGSS Science and Engineering Practices: Analyzing and Interpreting Data and Engaging in Argument from Data; NGSS Crosscutting Concept: Cause and Effect)

C. Using the same buoy, students select one weather element to use to create a data table and graph. Students will first create an appropriately labeled data table to represent seven distinct data points over a period of time. The students will then use the data table and the Create a Graph website to create an appropriate graphical representation of the data for their selected buoy.

Discussion and Application Questions
1. What are some of the functions of buoys?
2. Is the weather data the same for all of the buoys in Lake Michigan at the same time on the same day? Why or why not?
3. How does Lake Michigan impact the weather on the land surrounding it?
4. What types of changes did you find in the data you analyzed? What could account for those changes?

Extensions
- Students compare buoy data to local weather data by creating a multiple-line graph.
- Students can compare buoy data from the same time on different days or years, or at different depths.
- Students can compare and contrast their data tables and graphs with the data tables and graphs from classmates and explain similarities and differences.
- Students can check on the inferences regarding their buoy data by examining the local weather reports and weather information prior to and after the date they examined.

Other Resources

Create a Graph – Can be used to create various graphs -
http://nces.ed.gov/nceskids/createagraph/

Buoy Descriptions – Provides pictures and descriptions of various buoys -
http://www.boaterlicences.com/online_course_buoys.php

Adopt a Buoy **Name** ______________________________

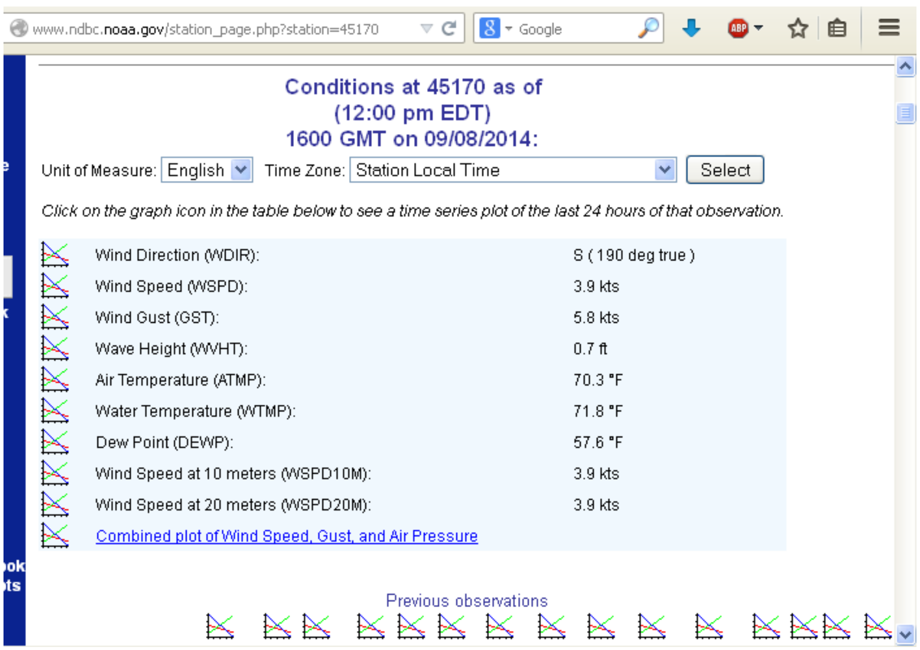
Student Worksheet

1. Go to the web website: http://www.ndbc.noaa.gov/. The red, orange, and yellow diamonds represent lake buoys. Select one of these buoys to "adopt" for a graphing activity. It is best to select a yellow buoy.

2. Click on the diamond and a dialogue box will open.
   Write the number and location for the buoy you have adopted:

   ____

3. Now select the "View Details" link. Your screen should look like this:



4. Select a graph for one of the items listed by clicking on the graph icon. Provide a summary of the data. For instance, did the temperature go up? Then, make an inference based on the observation. What do you think was happening at that time? Why?

   ____
   ____
   ____
   ____
   ____

5. Okay, let's make a graph of your own. Begin by selecting an item to graph. To do this, scroll down to the Previous Observations section. Determine which item you would like to graph. I am graphing data about:

   ____

6. Now, make a data table using the information from the page. You need at least seven data sets. Use the data from the data table to create a graph. Be sure that your graph accurately depicts the data. You may use the Create a Graph website or you may draw the graph on your own.

Downloading Buoy Data

Buoy data can be accessed from various sources, and different websites have their own way of displaying and sharing data. Appendix A. explains how to download data from three main sources.

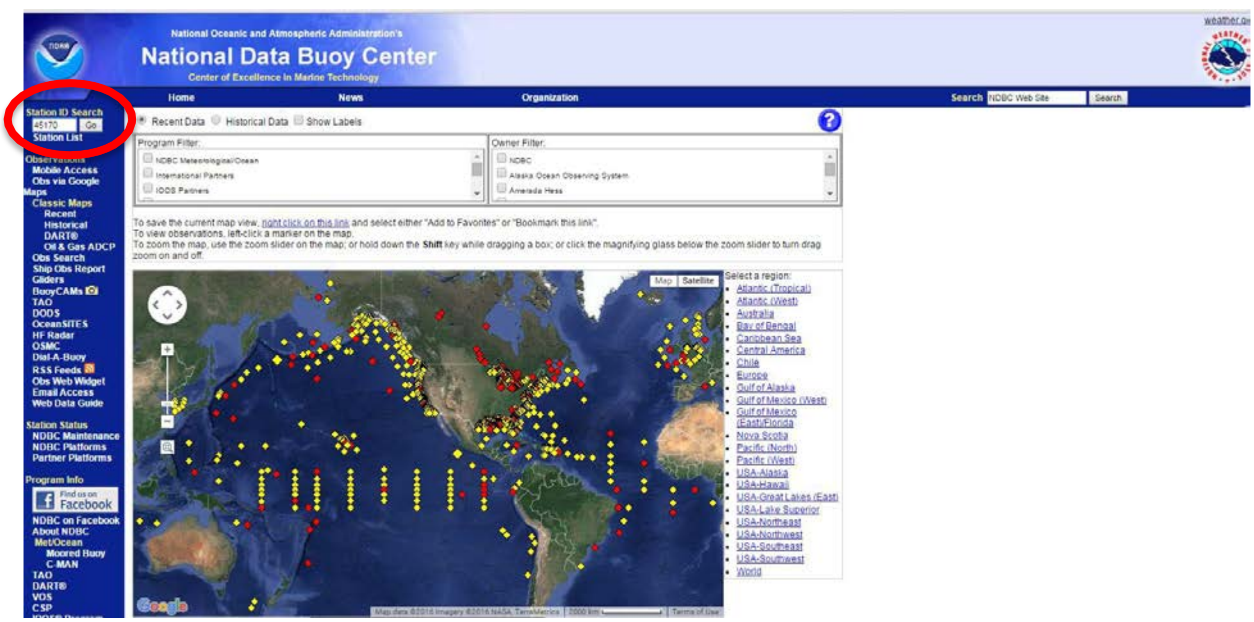
- The National Data Buoy Center is a comprehensive listing of real-time monitoring assets deployed all over the world.
- GreatLakesBuoys.org displays data from many (but <u>NOT</u> all) real-time monitoring buoys currently in use in the Laurentian Great Lakes.
- Illinois-Indiana Sea Grant displays data from real-time buoys in the Illinois and Indiana waters of Lake Michigan.

National Data Buoy Center: Downloading Data

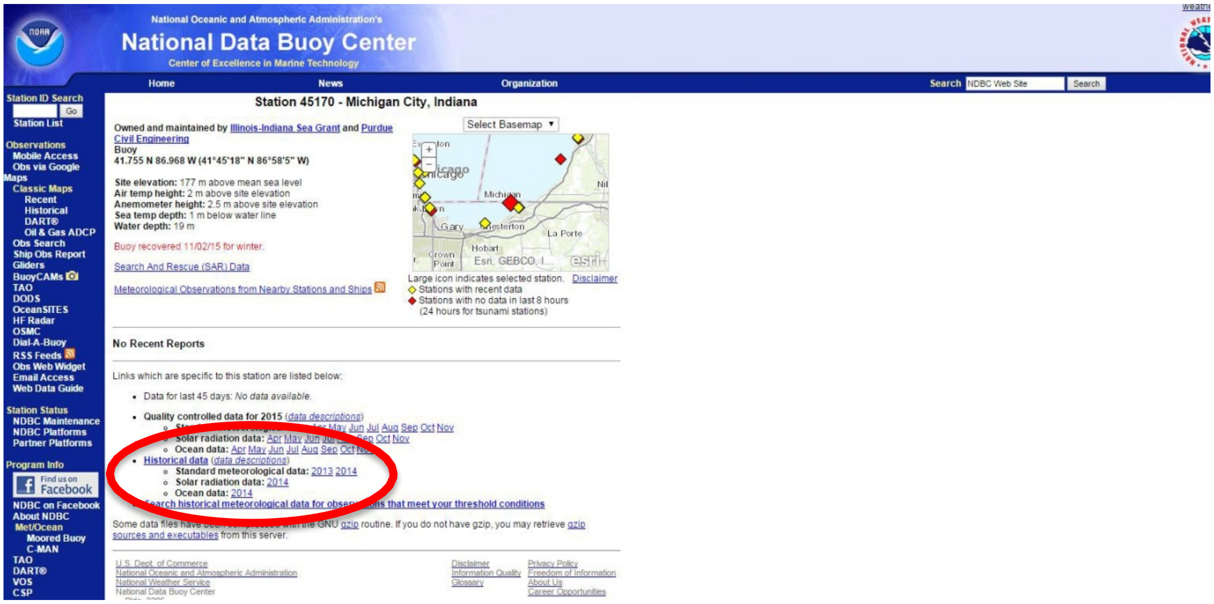
(www.ndbc.noaa.gov)

File format: Text file (.txt)

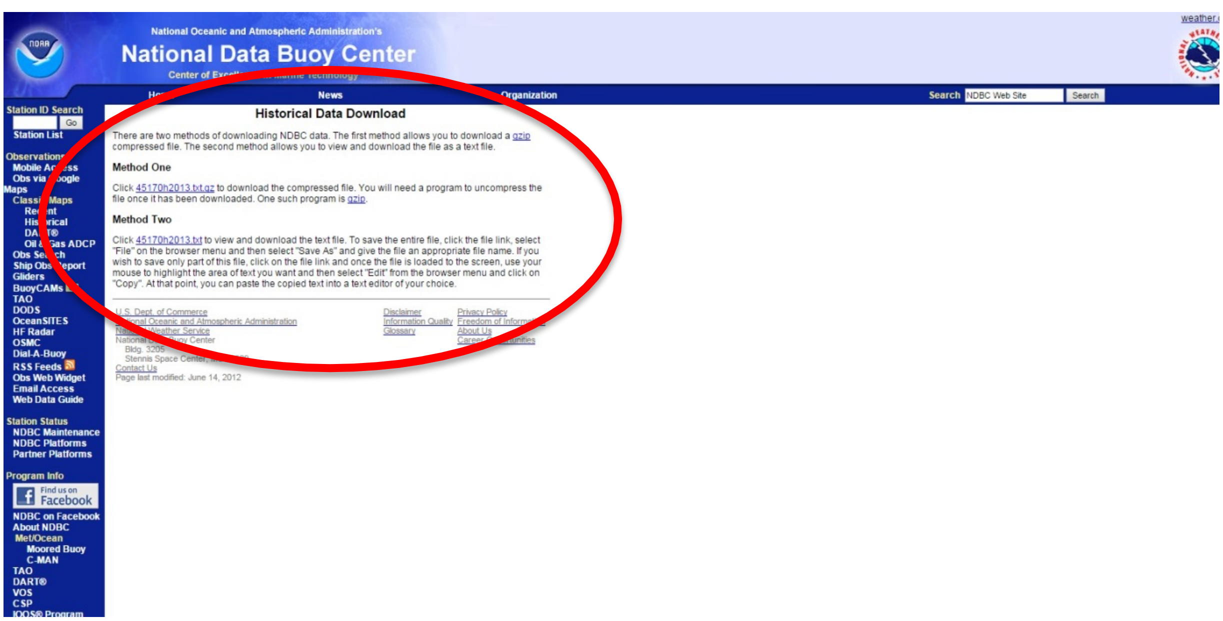
1. Search using the buoy ID or scrolling the map (Michigan City, IN buoy: 45170, Wilmette, IL buoy: 45174).



2. Select "Historical Data" (note – if buoy is currently deployed, you may need to scroll down to find this).



3. Follow the directions for "Method One" or "Method Two". If following Method Two, you can paste the data directly into a blank Excel worksheet. If following Method One, see "Opening a .txt or .csv file in Excel."

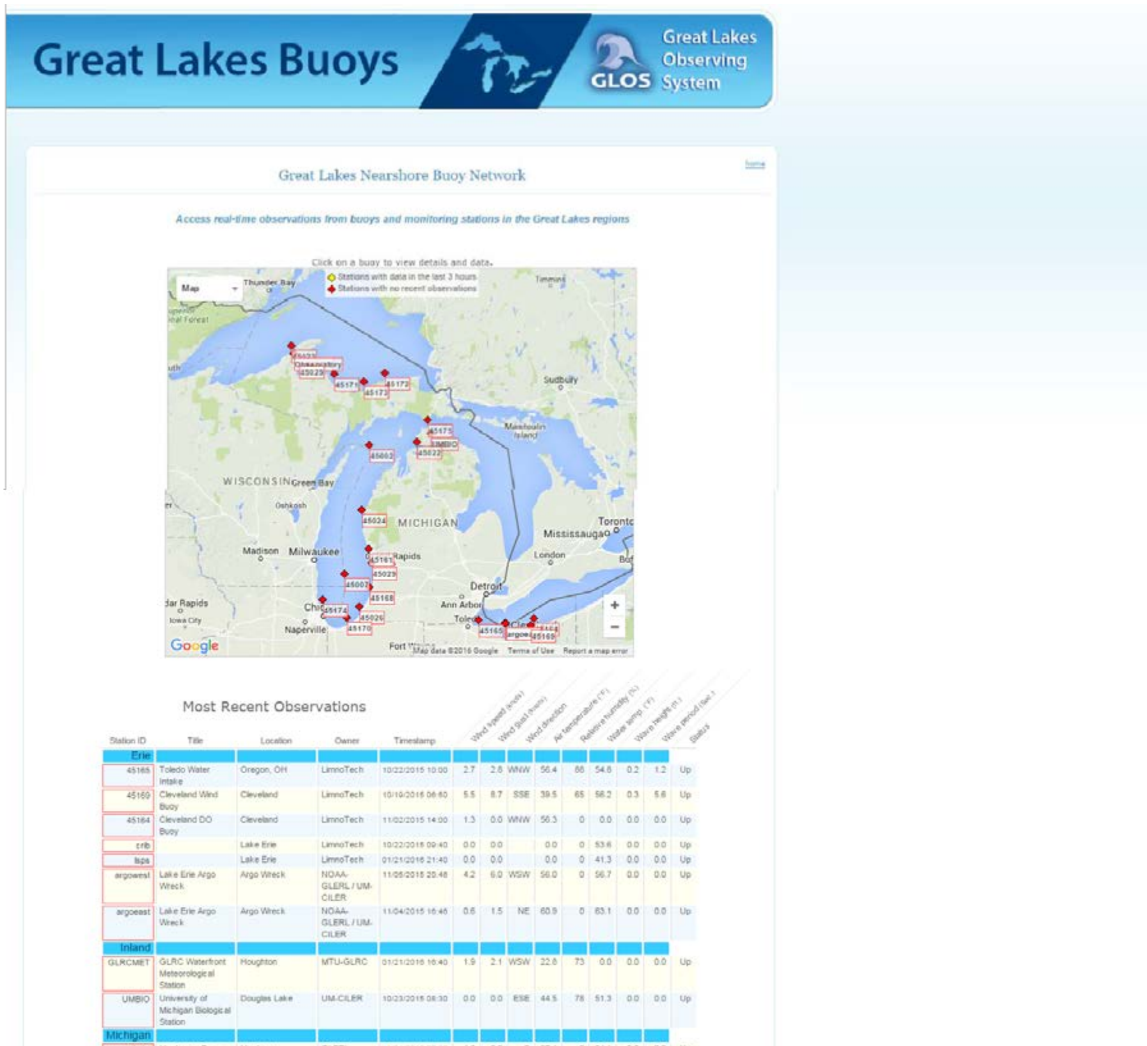


GreatLakesBuoys.org: Downloading Data

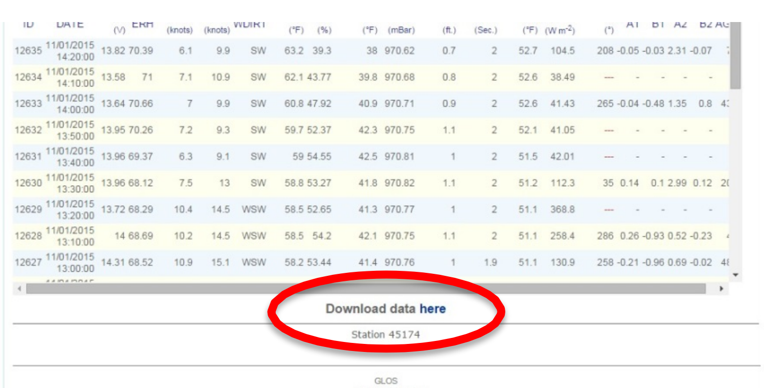
(www.greatlakesbuoys.org)

File format: Comma separated text file (.csv)

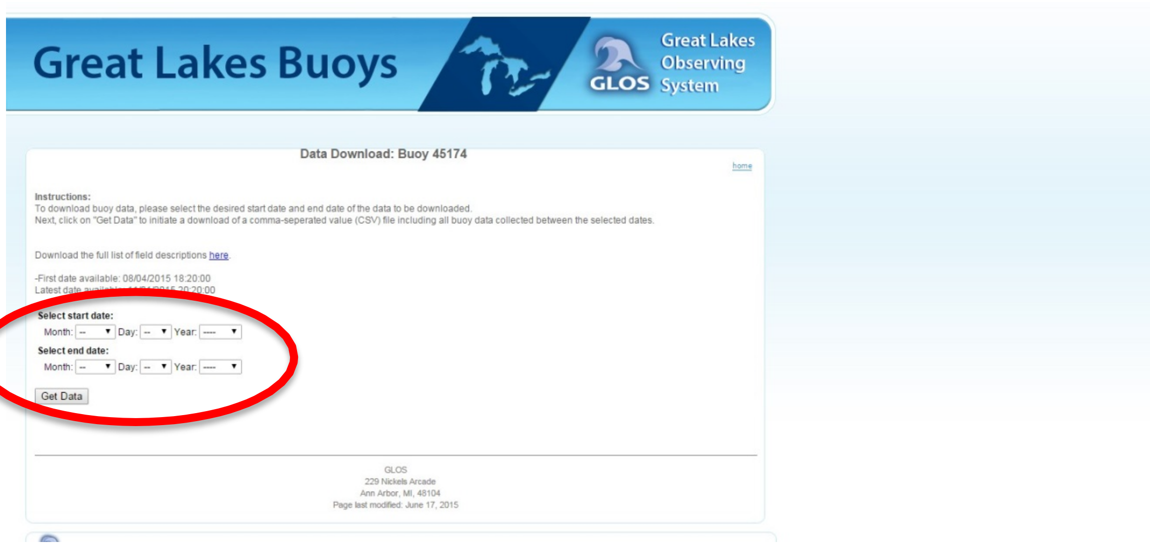
1. Select the buoy you would like data for via the map or the table beneath the map.



2. Scroll down to "Download data here."



3. Select the range of data you would like. You can search by specific start and end dates, but the number of years available will change depending on the buoy. The data will be saved to your "Downloads" file.

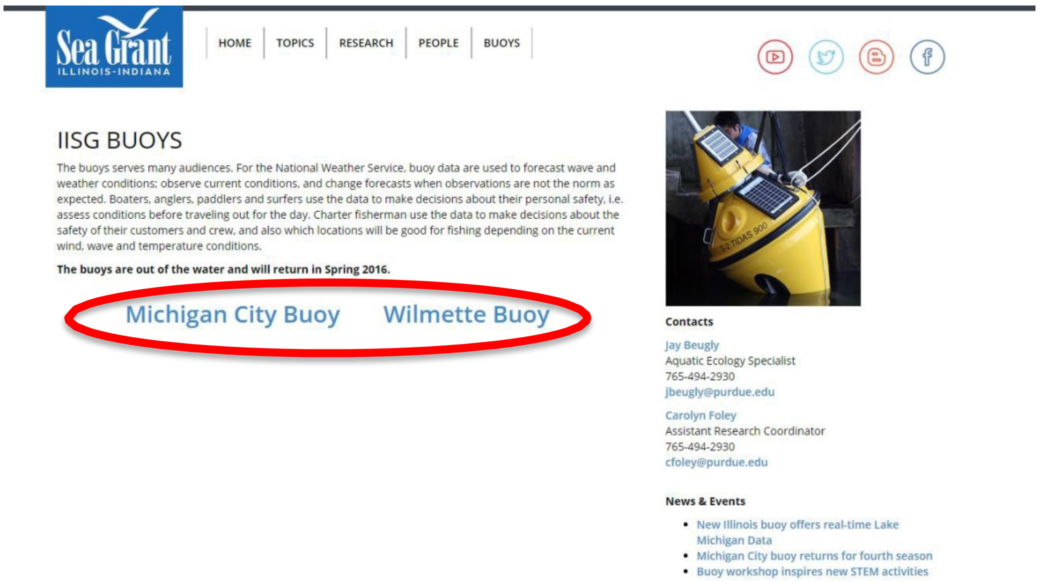


Illinois-Indiana Sea Grant: Downloading Data

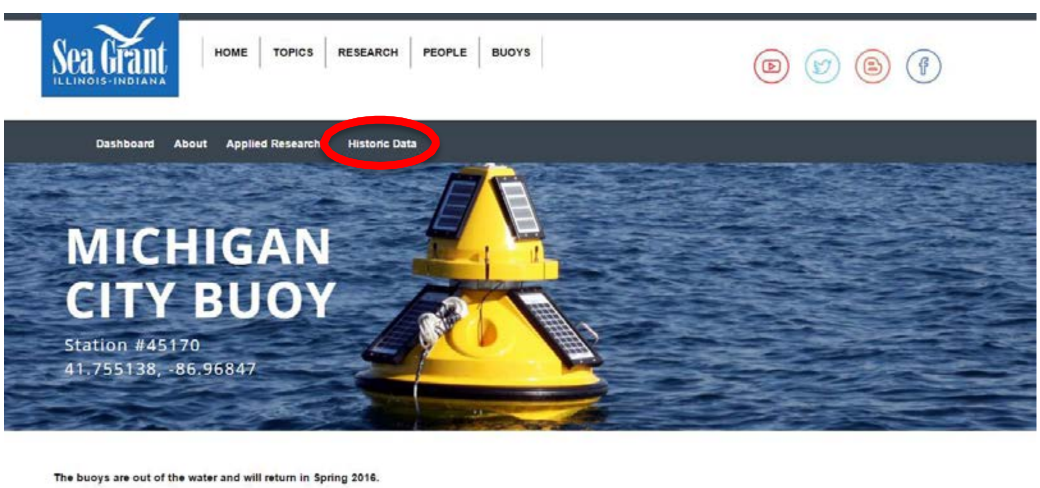
(http://iiseagrant.org/buoys.php)

File format: Comma separated text file (.csv)

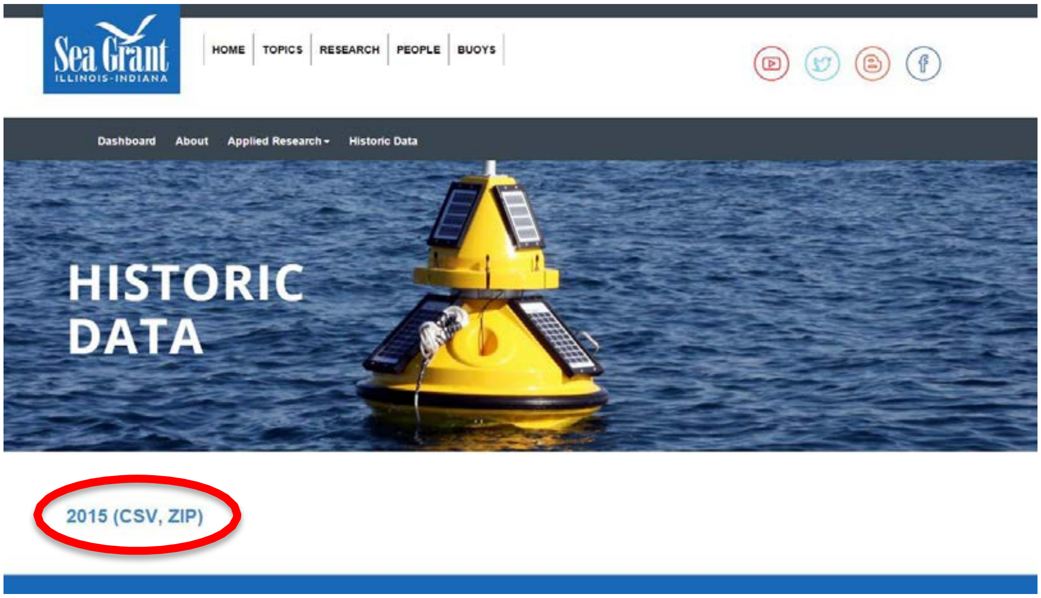
1. Pick the buoy you would like data for (as of Jan. 21, 2016, options are Wilmette, IL buoy or Michigan City, IN buoy).



2. Click on the "Historic data" tab.



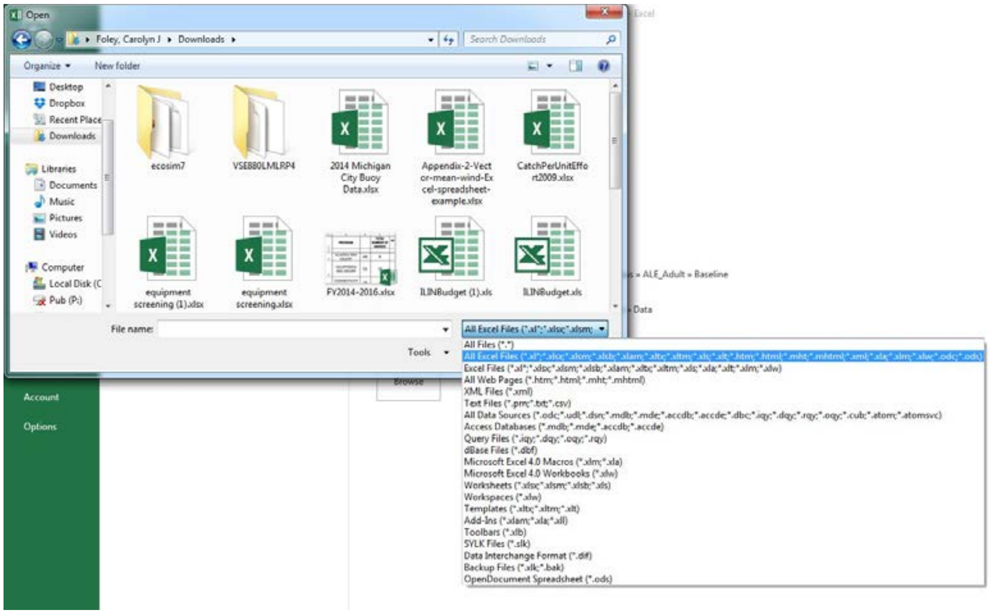
3. Select the year you would like data for. You must download an entire year's worth of data, and the number of years available will change depending on the buoy. The data will be saved to your "Downloads" file.



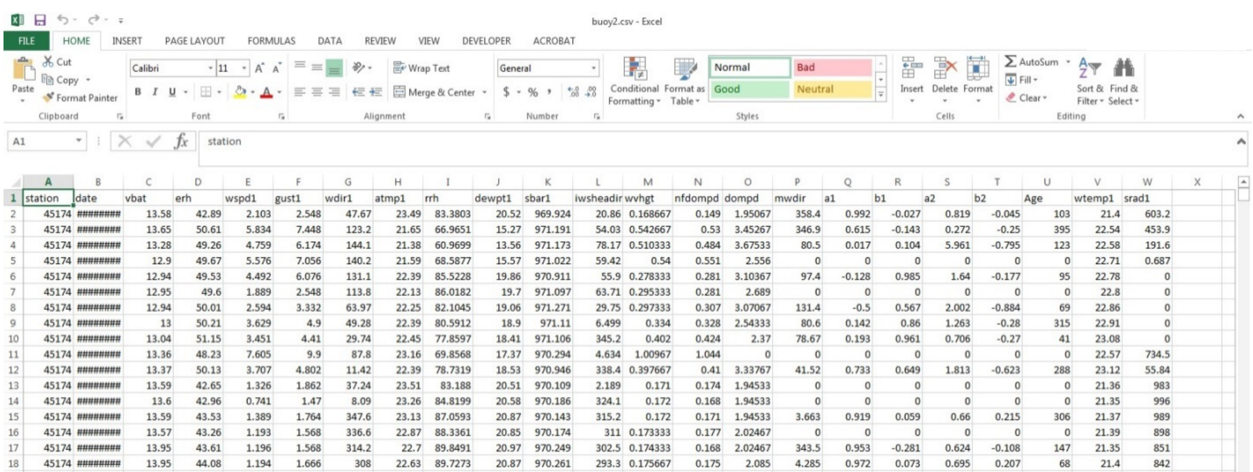
Opening a Text File in Excel

(similar in all versions of Excel)

1. When navigating to the file you want to open, be sure you have the right "File type" selected. Depending on the version of Excel, this may be called slightly different things. However, there is always a drop box where you can change the default from "Excel files (.xls, .xlsx, (...)" to "Text files (.prn, .txt, .csv)". Once you do this, the downloaded file should show up as an option for opening.



2. Data should show up in proper columns. However, you may need to define how the data are delimited. In .csv files, this is with a comma. In .txt files, sometimes tabs or spaces are used. Be sure to test this before conducting the lesson. If you have questions, feel free to contact the authors of this publication.



3. Descriptions of what the headers mean can be found on each site. More information can also be found at http://www.ndbc.noaa.gov/faq.shtml, http://greatlakesbuoys.org/FieldDescriptions.txt.)

Great Lakes Literacy

Great Lakes literacy is an understanding of the Great Lakes' influences on you and your influence on the Great Lakes

A Great Lakes literate person:

- Understands the essential principles and fundamental concepts about the characteristics, functioning and value of the Great Lakes.
- Can communicate accurately about the Great Lakes' influence on systems and people in and beyond their watershed.
- Is able to make informed and responsible decisions regarding the Great Lakes and the resources of their watershed.

Essential Principles for Great Lakes Learning match those of Ocean Literacy:

OCEAN LITERACY PRINCIPLES		GREAT LAKES LITERACY PRINCIPLES	
1	The Earth has one big ocean with many features.	1	The Great Lakes, bodies of fresh water with many features, are connected to each other and to the world ocean.
2	The ocean and life in the ocean shape the features of Earth.	2	Natural forces formed the Great Lakes; the lakes continue to shape the features of their watershed.
3	The ocean is a major influence on weather and climate.	3	The Great Lakes influence local and regional weather and climate.
4	The ocean makes earth habitable.	4	Water makes Earth habitable, freshwater sustains life on land.
5	The ocean supports a great diversity of life and ecosystems.	5	The Great Lakes support a broad diversity of life and ecosystems.
6	The ocean and humans are inextricable interconnected.	6	The Great Lakes and humans in their watersheds are inextricable
7	The ocean is largely unexplored.	7	Much remains to be learned about the Great Lakes.
		8	The Great Lakes are socially, economically, and environmentally significant to the region, the nation, and

Great Lakes Literacy Principles
http://www.cgll.org/for-educators/great-lakes-literacy-principles/

Great Lakes Literacy Principle 1

The Great Lakes, bodies of fresh water with many features, are connected to each other and to the world ocean.

A: The Great Lakes are a dominant physical feature of North America and form part of the political boundary between the United States and Canada.

B: The Great Lakes system includes five Great Lakes (Superior, Huron, Michigan, Erie and Ontario), Lake St. Clair and the connecting channels, along with many harbors and bays. Each lake has distinctive basin features, circulation and ecology.

C: The Great Lakes contain nearly 20 percent of the world's fresh surface water and have a coastline longer than the East coast of the United States. Most of North America's fresh surface water (95%) is in the Great Lakes.

D: The Great Lakes, their respective watersheds and waterways, and the ocean are all connected. Within the Great Lakes system, water flows from Lake Superior and Lake Michigan to Lake Huron, through Lake St. Clair into Lake Erie, over Niagara Falls and into Lake Ontario before flowing through the St. Lawrence River into the ocean. Rivers and streams transport nutrients, dissolved gases, salts and minerals, sediments and pollutants from watersheds into the Great Lakes.

E: The Great Lakes are an integral part of the water cycle and are connected to the region's watersheds and water systems. Changes in water systems affect the quality, quantity and movement of water, including retention time.

F: Water currents circulate within the Great Lakes and are powered by wind, waves, energy from the sun and water density differences. The shape of a lakebed and its geographic orientation, the direction of the prevailing winds, the shores and the structures along the shores influence the path of circulation. Circulation between the lakes is driven by gravity.

G: Lake level is the height of the Great Lakes relative to sea level. Lake level changes are caused by variations in precipitation, evaporation, runoff, and snow melt, as well as wind and waves. While tides are typically not discernable in the Great Lakes, seiches are common in the Lakes.

H: The Great Lakes stratify in the summer and in winter under ice cover, forming distinct layers based on water temperature differences. Turnover occurs in the spring and fall when cooler weather minimizes temperature differences and the layers mix. Turnover is the main way that oxygen and nutrient-poor water in the deeper areas of the lakes can be mixed with oxygen and nutrient-rich surface water.

I: Although the Great Lakes are large, they are finite and their resources are limited.

Great Lakes Literacy Principle 2

Natural forces formed the Great Lakes; the lakes continue to shape the features of their watershed.

A: Ancient igneous and metamorphic rocks form portions of the upper Great Lakes basin. Other rocks underlying the present day Great Lakes and surrounding watershed are sedimentary, originating during a time when shallow tropical seas covered the basin. Many of the rocks now exposed on land were deposited and shaped during the advance and retreat of glaciers.

B: During the Ice Age, mile-thick sheets of ice covered the Great Lakes region multiple times depressing the crust with their weight. Ancient beach ridges mark previous lake shorelines. Since glaciers retreated (about 10,000 years ago), Earth's crust has been adjusting upward in a process of isostatic rebound that continues today.

C: Lake level changes influence the physical features of the Great Lakes coast. Lake water levels show changes and patterns that vary over periods of hours to millennia.

D: Erosion - the wearing away of rock, soil and other earth materials - occurs in coastal areas as wind, waves, and currents in rivers and the Great Lakes move sediments.

E: Sediments are a product of erosion and consist of fragments of animals, plants, rocks and minerals. Sediments are classified by grain sizes, from silt and clay to sand, cobbles and boulders. Sediments are seasonally redistributed by waves and coastal currents and help maintain beaches and coastal wetlands.

Great Lakes Literacy Principle 3

The Great Lakes influence local and regional weather and climate.

A: The Great Lakes affect weather and climate by impacting the basin's energy and water cycles. Changes in the Great Lakes' water circulation, water temperatures and ice cover can produce changes in weather patterns.

B: The Great Lakes warm by absorbing solar radiation. Lake temperatures are also affected locally by the temperature of inflowing river waters. The Great Lakes lose heat by evaporation and by warming the overlying air when the atmosphere is cool. After water vapor is released into the atmosphere, it condenses and forms precipitation, some of which falls within the Great Lakes Basin.

C: The Great Lakes modify the local weather and climate. Because water temperatures change more slowly than land temperatures, lake waters gain heat in summer and release heat during cooler months. This results in cooler springs, warmer falls, delayed frosts and lake effect snow.

D: The Great Lakes have a significant influence on regional climate by absorbing, storing and moving heat and water. Lake effect precipitation can occur downwind when major weather systems move over the lakes.

E: The Great Lakes are influenced by larger climate change patterns affecting North America and the world. Climate patterns in the Great Lakes are changing, with warmer and drier conditions predicted.

Great Lakes Literacy Principle 4

Water makes Earth habitable; fresh water sustains life on land.

A: Fresh water has unique properties. Its density and electrical conductivity (a measure of salinity) are lower than that of salt water.

B: Water is essential for life. All living processes occur in an aqueous environment.

Great Lakes Literacy Principle 5

The Great Lakes support a broad diversity of life and ecosystems.

A: Life in the Great Lakes ranges in size from the smallest blue-green bacteria, such as Microcystis, to the largest animal that still lives in the Great Lakes, lake sturgeon.

B: Most life in the Great Lakes exists as microorganisms. Microorganisms such as phytoplankton and cyanobacteria are the most important primary producers in the lakes.

C: The Great Lakes' watershed supports organisms from every kingdom on Earth.

D: Great Lakes biology provides many examples of life cycles, adaptations and important relationships among organisms, such as symbiosis, predator-prey dynamics and energy transfer.

E: The Great Lakes ecosystem provides habitat for terrestrial and aquatic species. The Great Lakes are three-dimensional, offering vast living space and diverse habitats from the shoreline and surface down through the water column to the lake floor.

F: Great Lakes habitats are defined by environmental factors. As a result of interactions involving abiotic factors such as temperature, clarity, depth, oxygen, pH, light, nutrients, pressure, substrate type and circulation, life in the Great Lakes is not evenly distributed temporally or spatially. Abiotic factors within the Great Lakes can change daily, seasonally or annually because of natural and human influences.

G: Ecosystem processes (abiotic conditions, prey availability and predation) influence the distribution and diversity of organisms from surface to bottom and nearshore to offshore.

H: Wetlands, including coastal marshes and freshwater estuaries, provide important and productive nursery areas for many aquatic and terrestrial species which rely on these habitats for protective structure, hunting grounds, migration stops, and raising offspring.

I: Life cycles, behaviors, habitats and the abundance of organisms in the Great Lakes have been altered by intentional and unintentional introduction of non-native plant and animal species.

Great Lakes Literacy Principle 6

The Great Lakes and humans in their watersheds are inextricably interconnected.

A: The Great Lakes affect many human lives. They supply fresh water to more than 40 million people. They are a source of drinking water and food, as well as mineral and energy resources.

B: One-third of the North American population lives in the Great Lakes' watershed. Some of the most urbanized regions in the United States and Canada can be found around the Lakes.

C: The Great Lakes are affected directly by the decisions and actions of people throughout its watershed which includes parts of the states of Illinois, Indiana, Michigan, Minnesota, Ohio, Pennsylvania, New York, and Wisconsin, the Canadian provinces of Ontario and Quebec, and tribal lands.

D: Local and national laws, regulations and resource management affect what is put into and taken out of the Great Lakes. Shoreline development and industrial or commercial activities lead to point and non-point source pollution. Humans have altered the biology of the lakes and the viability of species through harvesting, species introduction, and nutrient loading.

E: Coastal regions along the Great Lakes are impacted by land use decisions and natural hazards. Physical modifications (changes to beaches, shores and rivers) can exacerbate effects of erosion, storm surges and lake level changes.

F: To ensure continued availability of Great Lakes assets, people must live in ways that sustain the lakes. Individual and collective actions are needed to effectively conserve and manage Great Lakes resources for the benefit of all.

Great Lakes Literacy Principle 7

Much remains to be learned about the Great Lakes.

A: Exploration and understanding of Great Lakes interactions and links among diverse ecosystems and people are ongoing. Such exploration offers great opportunities for inquiry and investigation.

B: Understanding the Great Lakes is more than a matter of curiosity. Exploration, inquiry and monitoring promote better understanding and protection of Great Lakes ecosystems, resources and processes.

C: Over time, use of Great Lakes resources has changed significantly. The future sustainability of Great Lakes resources depends on our understanding of those resources and their potential and limitations.

D: New technologies and methods of observation are expanding our ability to explore the Great Lakes. Freshwater scientists rely on such tools to monitor conditions in the Great Lakes and provide information to policy makers and leaders in coastal communities.

E: Models help us understand the complexity of the Great Lakes. Models process observations, describe interactions among systems, expose information gaps and forecast change.

F: Exploring, understanding and communicating about the Great Lakes ecosystem are interdisciplinary efforts. They require close collaboration among professionals in science, technology, engineering and math, as well as public outreach and education.

Great Lakes Literacy Principle 8

The Great Lakes are socially, economically, and environmentally significant to the region, the nation, and the planet.

A: The Great Lakes are a source of inspiration, recreation, rejuvenation and discovery. They are also an important element in the heritage of many cultures.

B: The waters of the Great Lakes have been significant to historical settlement and development. The lakes' names and the names of many cities, counties and landmarks along their shores have Native American or immigrant origins. This fresh water resource will continue to play a role in future habitation of the area.

C: The Great Lakes' moderating effects on climate influence the human culture, activities, agriculture and health of adjacent coastal areas.

D: Waterborne commerce moves millions of tons of cargo annually through the Great Lakes. Shipping is an economically efficient method of transporting raw materials, finished goods and agricultural products. However, shipping is also a vector for non-native species, several of which may be detrimental to the Great Lakes ecosystem.

E: The economy is diverse in the Great Lakes, with major sectors in industry, recreation and tourism, agriculture, commercial and sport fisheries, forestry, and mining.

F: The Great Lakes were dramatically degraded and challenged by human endeavors in recent times. Basic ecosystem processes have been restored through individual and collective efforts. Proper foresight and informed decision making will continue to make the Great Lakes a model of environmental protection, restoration and innovation.

Background Reading: Lake Michigan Physical Processes

Seasonal cycle of heating and cooling in Lake Michigan

Lake Michigan's waters undergo an annual of cycle of heating and cooling. This cycle has an important effect on lake water temperatures, which in turn determine circulation characteristics, ecosystem functioning, and the mixing of contaminants. A key element of the seasonal cycle of heating and cooling is the thermal stratification that occurs in the summer time, when warm, less dense surface waters lie atop colder, denser waters at the bottom of the lake.

The lake heats up and cools down throughout the year due to heat transfer at the water surface. A 30 year history of the seasonal cycle of Lake Michigan's surface temperature is shown in the figure at right. 2014 was one of the coldest years on record, in spite of what we know about the warming trends of Lake Michigan's waters over that period (Figure 1).

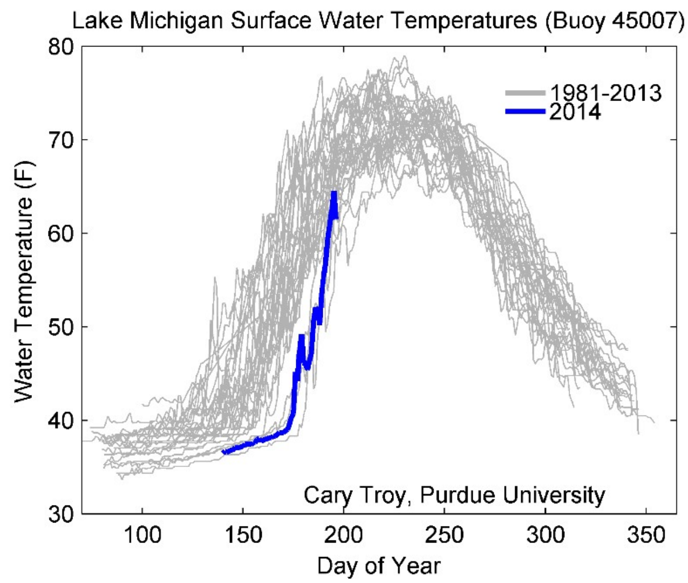


Figure 1. Surface water temperatures measured in the middle of Lake Michigan, from Buoy 45007.

Spring - the onset of thermal stratification

In the springtime, the lake starts warming up, especially in the lake shallows. Strong winds still keep the lake relatively well-mixed in the vertical direction. As the lake warms further, the zone of warm nearshore water slowly enlarges, migrating offshore until the entire lake has warmed. Once this occurs, the surface waters start preferentially absorbing heat, and summer thermal stratification begins to set in.

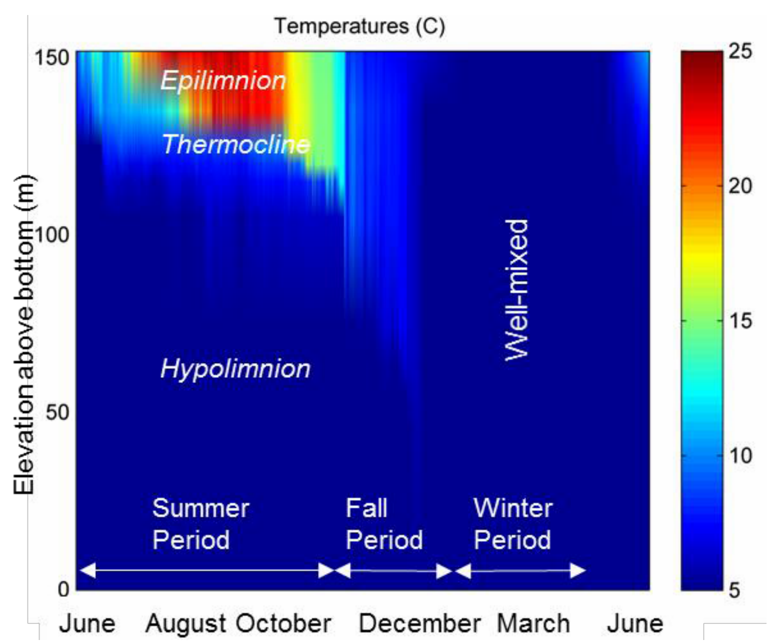


Figure 2. Measurements of Lake Michigan water temperature (in degrees C), showing the seasonal cycle of warming and cooling. Data were obtained from temperature sensors placed along a thermistor chain in the center of Lake Michigan's southern basin in 1998-199

Summer – when the lake is stratified

In the summer, the lake is *thermally-stratified*, with warm surface water lying atop colder, denser bottom water (like a latte, with milk on top of coffee). We call the surface waters the *epilimnion*, or *mixed layer*, and the bottom waters are called the *hypolimnion*. The region separating the two water masses is termed the *thermocline* (also called the *metalimnion)*. The thickness of the surface layer is largely set by the depth to which sunlight can penetrate the water. During the summer, these two water masses are largely distinct from one another, as their density difference prevents mixing of substances across the thermocline. Also, in summer, the winds are relatively weak, and so the surface waters are not as turbulent as in other parts of the year.

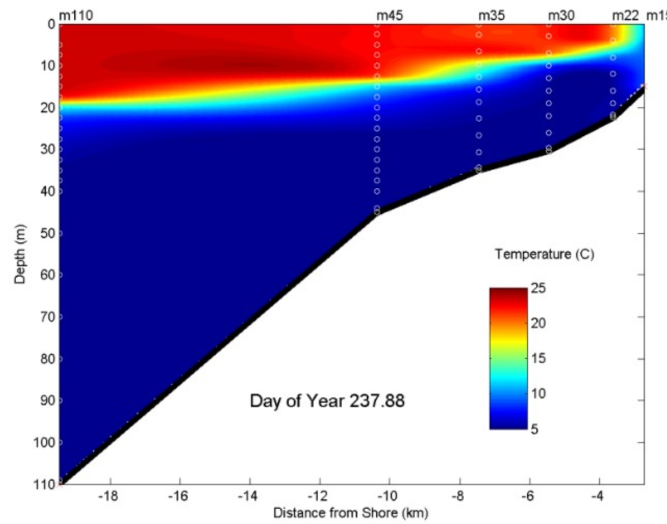


Figure 3. Side view of Lake Michigan's thermal structure as shown during an upwelling event. Image created from temperature sensor data (circles on plot).

Autumn – the "fall overturn"

In the autumn period, the winds over Lake Michigan increase, and the air temperature begins to drop. These two effects combine to cool the surface waters, leading to an unstable configuration of colder water atop warmer water, and the phenomenon of *buoyant convection*. Buoyant convection is simply the sinking of cold water until it reaches an equilibrium depth, where it is neutrally buoyant. The effect of buoyant convection and greater surface agitation by the wind has the effect of steadily deepening the mixed layer in the autumn period. As the surface waters cool, the mixed layer continues to deepen, until finally the lake becomes vertically homogenous – isothermal – and the complete "overturn" has occurred. Because Lake Michigan is so deep, complete overturn does not usually occur until late December.

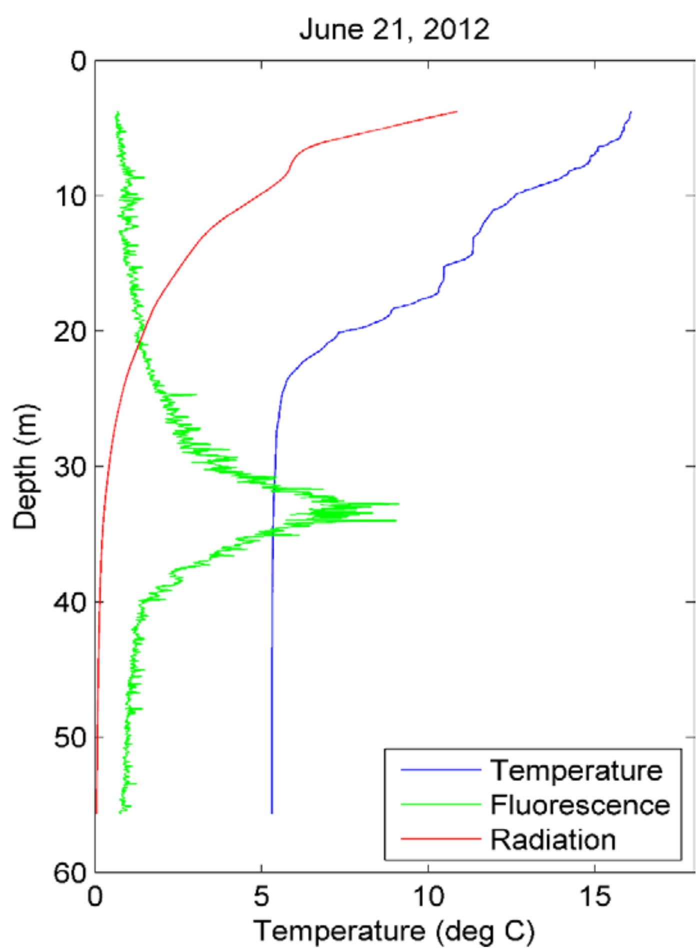


Figure 4. Vertical profiles of temperature, chlorophyll fluorescence, and solar radiation. Data taken by lowering a CTD (Conductivity-Temperature-Depth) instrument through the water column near Milwaukee, WI. Fluorescence is a measure of phytoplankton in the water column, which often aggregate at the base of the thermocline where they have access to both light from above and food from below

Winter – the well-mixed period

In winter, the waters are nearly isothermal from top to bottom – and water freely circulates vertically in the lake as a result of strong winds and intense storms. Interestingly, the winter is the one period of the year when the lake can have colder water on top of warmer water and still be stably stratified vertically (why?). Additionally, for many of the Great Lakes, ice plays an important role in the winter time.

Exercises: Seasonal cycle of heating and cooling in Lake Michigan

1. Create a stratified lake in a container (a glass, aquarium, or other clear vessel), by carefully pouring a light fluid on top of a heavier fluid. Examples include cold/warm water; salty/fresh water; vinegar and oil; and whatever you can find in your cabinets! Use food coloring to distinguish the different fluids.
    a. Looking from the side, using an erasable marker, label the *epilimnion, hypolimnion, and metalimnion.*
    b. What is causing the density stratification in your lake? What causes density stratification in Lake Michigan? What causes density stratification in the ocean?
    c. Inject some dyed water into different areas of the lake. What do you notice about how the water mixes? Does the water mix freely throughout the lake? If a pollutant is spilled at the lake surface, how do you think it will mix in (i) summer and (ii) winter?
    d. Tilt your lake to the side, and then let it rebound. Watch the metalimnion. What do you notice? Do you see sloshing?
2. List five commonly available fluids that are light, and five that are heavy. Then, rank them in your perceived order from heaviest to lightest. Test the order of your list by performing internet research and/or performing simple experiments where you pour different fluids into a tall glass.
3. Have a contest to see who can pour the most fluids into a container, on top of one another, in a stable configuration. Then, pair students and have them try to determine each other's fluids.
4. Why is the winter time the only period when the lake can have colder water atop warmer water AND be stable? To answer this question, examine how temperature affects water density.
5. What is the relationship between the vertical profiles shown in Figure 3, with the color plot given in Figure 2?
6. Values of freshwater density are given for various temperatures below. What is the temperature at which the water density is greatest? In the deepest parts of the lake, what do you think the water temperature is, and why?
7. Download surface water temperature data from the Michigan City buoy. Plot the surface temperature as a function of the day of the year (can also do this for multiple years). When is the surface water temperature greatest?
    a. Repeat the exercise for the air temperature. How do the two results compare, and why do you think they differ

Currents in Lake Michigan

(Graphics to include: drifter tracks, ADCP animations, animations of wind shear stress)

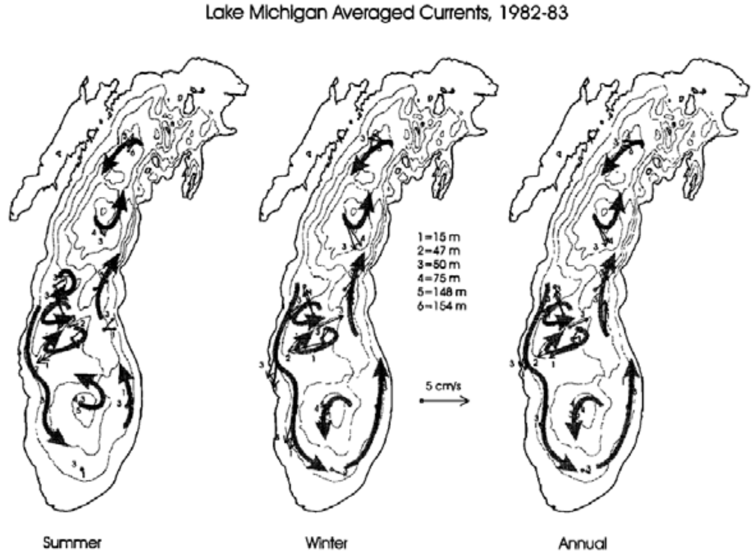


Figure 6. Observed circulation patterns in Lake Michigan, for 1982-1983. Figure 8 from Beletsky and Schwab (2001; permission pending).

Almost all motion in the Great Lakes begins with the wind. As the wind blows over the lake, a variety of motions will be excited, and the motion that you observe in the lake on any given day will be a combination of all of these processes. In general these motions fall into three categories:
(1) waves; (2) low-frequency currents; and (3) turbulence.

Waves

What would a lake be without a wave? The most ubiquitous features in Lake Michigan are water waves, but there are numerous types of waves in the lake, ranging from the regular waves you see at the beach to whole-lake sloshing motions, where the entire lake acts almost like a giant sloshing bathtub. The period of these waves ranges from several seconds (for waves at the beach) to almost a full day (when the whole lake sloshes back and forth). To lowest order, waves only serve to move water back and forth, but they play an important role in the shallow waters of the lake, creating currents that resuspend sediments and transport materials to and from beaches. To learn all about waves in Lake Michigan, click here.

Low-frequency currents

The more eye-catching waves and turbulence that you see in the lake are superimposed on top of slower, more persistent, *low-frequency currents.* These currents are sometimes termed *mean currents*, because they are the mean, or average currents that persist over long periods of time (days to months). The motions associated with low-frequency currents are generally slower, say 1-10 cm/s, but they are important because they dictate the long-term transport of important materials in the lake (phytoplankton, larval fish, contaminants, and nutrients).

Unlike their ocean counterparts like the Gulf Stream and the Kuroshio, low-frequency currents in Lake Michigan are more variable and less predictable, because Lake Michigan is much more at the mercy of the weather (winds and temperatures) than the ocean. Nevertheless, researchers have analyzed water current measurements and performed computer simulations of the flow in Lake Michigan and found several persistent circulation patterns, as shown below. Because Lake Michigan has two distinct basins – north and south – and because currents tend to follow the lake bathymetry, the lake motion tends to divide into two relatively distinct circulations: a northern basin *gyre* and a southern basin *gyre.* Each gyre and its flow can make either clockwise or counter-clockwise patterns. In general analysis suggests that both gyres circulate counter- clockwise, but on any given day the pattern can be quite different from this mean circulation pattern.

Turbulence

The third general class of motions in Lake Michigan is turbulent motions. We know from everyday life that turbulence is very important to mixing – this is why we stir the cream we put in our coffee! The same is true in Lake Michigan, where turbulence plays an important role of the mixing of a variety of substances, from phytoplankton to pollutants. The fundamental structures of turbulence are *turbulent eddies*, which exist in a range of sizes from very small (millimeters) to very large (hundreds of meters, for some large scale horizontal eddies). In spite of the importance of turbulence to mixing in the lake, it is still scientifically impossible to predict every turbulent motion due to its complexity and range of scales. But while science cannot predict the exact motions associated with turbulence, scientists work to predict the net effect of turbulence – enhanced mixing – by developing formulas that relate turbulent mixing to the things we can predict (like low frequency currents). These formulas are called *turbulent parameterizations.*

How exactly do winds cause water motion in the lake? Water currents in Lake Michigan are caused by the wind, which exerts a *shear stress* on the water surface, and accelerates water in the direction of the wind. As water moves to different parts of the lake, the water surface elevation will begin to differ across the lake, forming *pressure gradients* that additionally accelerate the whole water column, and maintain motion in the presence of friction from the lake bottom.

References

Beletsky, D., and D. J. Schwab (2001), Modeling circulation and thermal structure in Lake Michigan: Annual cycle and interannual variability, J. Geophys. Res., 106(C9), 19745–19771, doi:10.1029/2000JC000691.

Exercises: Currents in Lake Michigan

1. Near Milwaukee, the surface current is measured to be moving generally southward at 5cm/s. Approximately how long will it take for the water to travel from Milwaukee to Chicago?
2. A short-term record of surface currents measured in the middle of Lake Michigan's southern basin is provided here. What is the average current at this location (direction and magnitude)? If a particle on the water surface is released into these currents, can you calculate the path that it will follow over time? (*hint: remember that distance = speed x time)* Graph the particle's pathline over time. What do you notice about the particle path?
3. The water currents often vary substantially over the lake depth. An example of the average current velocities, as they vary over the lake depth, is given here. Why do you think that currents move faster near the lake surface, and slower near the lake bottom? How is fluid sliding over a surface different than one fluid sliding over another?

4. A long-term record of currents from Lake Michigan is provided here. Which season has the strongest currents? Why do you think this is?

Exercises: Waves in Lake Michigan

Lake Michigan has a rich spectrum of water waves, ranging from the short, choppy waves we see on the lake surface to very large waves where the whole lake sloshes back and forth (termed a "seiche"). The periods of these waves range from very short (several seconds) to almost a day.

A schematic showing the range of periods for each of the wave types is shown below:

Wave Type	Capillary waves (surface tension)	Wind waves (gravity)	Surface "seiche" (gravity)	Internal "seiche" (gravity)
Period Hours	*<1 second*	*1-10 seconds*	2-10 hours	15-18 hours
Charac teristic	Ruffles on the lake surface	Regular waves, like at the beach	Whole lake sloshes back and forth	Thermocline moves up and down

Table 1. Types of water waves important in Lake Michigan.

Short wind waves

While all waves in Lake Michigan are caused by the wind, we call the regular waves we observe at the beach "wind waves". These waves are very important to boaters and beachgoers, and are also responsible for resuspending lake sediments and transporting substances in the very nearshore region. We describe waves in terms of several fundamental descriptors:

- *Period* (T) – this is the amount of time associated with one wave – one complete cycle of the water surface going up and down (typical units: *seconds*). In reality, there are waves of many different periods, but typically one period will dominate.
- *Wavelength* (λ) – this is the horizontal length, along the water surface, that measures from one high point of the wave (termed the *crest*) to the next high point of the wave (typical units: *meters* or *feet*). An approximate relationship to estimate the wavelength from the wave period (T) and water depth (d) is: λ = 4π ... ? ?
- *Wave height* (H) – the height of the waves, from the top (*crest*) to the bottom *trough*).

Lake Michigan waves vary over the year with seasonally-varying wind strength and direction. In addition to the wind strength, a key variable that determines the wave characteristics is the *fetch,* which is the total water distance over which the wind blows. In the winter, Lake Michigan has its largest waves, when strong winds can blow from the north over the full axis of the lake (large fetch). In the summer, the waves are more mild, with weaker prevailing winds from the west/southwest (smaller fetch). In general, the larger the fetch, the larger the waves, and the longer the wave periods.

The dominant periods of the lake waves follow a seasonal pattern similar to the wind (click here to see data), with long period waves in the winter (5-6 seconds) and short period waves in the summer (3-4 seconds). During large fall and winter storms, however, periods of Lake Michigan waves can occasionally exceed 10 seconds. Even still, these periods are relatively small compared with ocean waves – particularly ocean swell arriving from far away - because Lake Michigan is a relatively small body of water with limited fetch.

What happens when waves approach the beach?

Waves in deep water do not feel the effects of the lake bottom until the water depth is equal to about ½ the wave's wavelength. As the waves approach the shore past this depth, the wave period will not change, but the wave will begin to slow down and the wavelength will shorten. In addition, in order to conserve energy, the waves will grow in amplitude as they slow down. Eventually, as the waves reach the shoreline, they grow in amplitude to a maximum height where they become unstable and break; a rule of thumb is that waves will break when their height is about 0.8 times the local water depth.

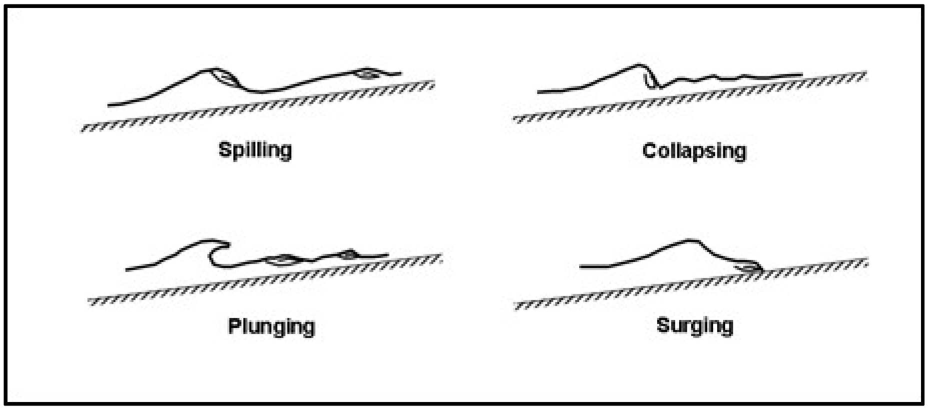


Figure 7. Breaking wave types observed at the beach. Source: Wikipedia.

Exercises: Water waves in Lake Michigan

5. Research has shown that water waves will break when their height grows to approximately 0.8 times the water depth. If a wave is observed to be breaking in water that is 0.5m deep, how large must the wave height be?
6. Download wave and wind data from the REAL TIME BUOY.
    a. How do you expect the wave period and/or wave height to vary with the month of the year? Test your expectation with a calculation or graph.
    b. How do you expect the wind speed to relate to observed wave periods and wave heights? Make a graph that tests your hypothesis, and determine whether your hypothesis is true.
7. Measure the period of water waves. This can be done in a small container, with water sloshing back and forth.
8. The period of a sloshing wave in a rectangular container can be estimated as $= \frac{2L}{\sqrt{gd}}$

    Here d is the water depth, L is the container length, and g is the acceleration due to gravity (either 32.2 ft/s or 9.8 m/s2, depending on the units you are using).
    a. Perform some simple experiments in a rectangular container to test this theory. Vary the depth for different experimental runs, and perform multiple experiments for a given water depth. Plot the observed period versus the theoretical period on a graph. Do they agree?
    b. After a strong wind burst from the west, Lake Michigan can slosh back and forth from west to east. If the average depth of the lake is about 85m, what is the expected period of this motion? Who travels faster, a person in a car, or a wave going from one side of the lake to the other?

c. Repeat exercise (b), except for a sloshing of Lake Michigan from north to south.

9. If you were going to re-create Lake Michigan with a scale model that was as long as a piece of paper, how many pieces of paper thick would your model be? Lake Michigan is approximately 450km long and 282m deep (at its deepest point). Do you think Lake Michigan is truly a deep lake?

Background Reading: Lake Michigan Fish

Lake Michigan supports some of the strongest commercial and recreational fisheries in all of the Great Lakes. From 1995 to 2011, recreational anglers around the lake spent about 5 million hours per year fishing, where the most popular species caught were yellow perch, Chinook salmon, Coho salmon, lake trout and rainbow trout (Hanson 2012). Recreational fishing effort was spread somewhat evenly around the lake, with greater activity near the southern basin and in Green Bay (Hanson 2012). From 1989 to 2009, commercial fishers of Lake Michigan contributed approximately 33% of the overall harvest for the entire Great Lakes fishery each year (GLMRIS 2012). The main species harvested were whitefishes, smelts, shads and herrings, while additional species harvested were salmon, trout, charrs, cods, perches, suckers, drums, catfishes and carp (GLMRIS 2012).

Different species live in different parts of the lake. The main species found in the nearshore (or depth less than 20 m) zone in recent years include yellow perch, round goby, rainbow smelt, spottail shiner, and alewife. Main species found in the offshore region include Chinook salmon, Coho salmon, lake trout, bloater and freshwater drum. Alewife and yellow perch are also major species found in the offshore region. Younger and/or smaller fishes, such as alewife, bloater and young yellow perch, tend to feed on invertebrates or very small fishes, and serve as prey to larger bodied piscivorous predators, such as adult yellow perch or Chinook salmon. Many of the salmon and trout found in Lake Michigan were introduced in the 20th century and are currently managed by various state and federal agencies through stocking programs.

Fishery managers need to be aware of stressors that might affect Lake Michigan fishes. Three stressors of note are invasive species, climate change, and habitat loss. Not all introduced species become invasive (for example, salmon were introduced to Lake Michigan but were never termed "invasive").

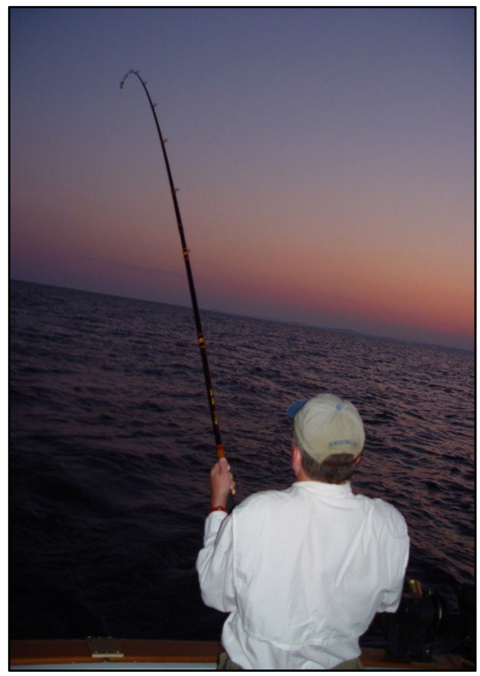
Invasive species show a capacity to quickly reproduce and have potential to overwhelm an ecosystem. They also cause environmental or economic harm to the system where they are introduced. Invasive species that have established since the mid-1990's, such as round goby, spiny water flea, and dreissenid (zebra and quagga) mussels, have completely altered the Lake Michigan food web. Much of the food energy that was previously up in the water column (the pelagic zone) has shifted toward the bottom, or benthic, region, where round gobies and dreissenids dwell. Round gobies compete with native fishes for nesting space and food, and will viciously defend their territories. They also eat eggs of other fishes. Spiny water flea (and the similar fishhook waterflea) are predatory zooplankton that compete with very young life stages of fish like alewife and yellow perch for limited food resources, and may not provide much nutrition to older fish when eaten themselves.

Dreissenid mussels have had the most devastating effects on the system, as they are proficient filter feeders (in some areas, able to filter the whole water column in less than 24 hours!) and strip important elements like phosphorus out of the water column to incorporate into their shells. They also grow together in clumps, or druses, and attach to docks, boats, and other permanent or semi-permanent structures that remain in the lake for a period of time (such as the IISG real-time monitoring buoy), potentially blocking important equipment.

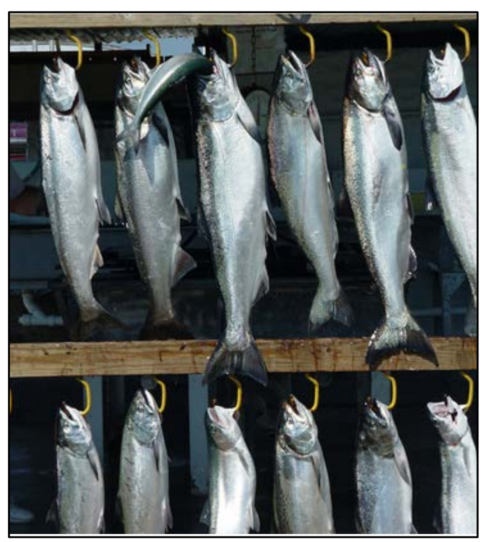
Climate change is expected to result in warmer water temperatures in Lake Michigan and other freshwater lakes. These warmer temperatures will likely affect the growth, reproduction and distribution of both fishes and their prey (Ficke et al. 2007, Rutherford et al. 2007). Effects may be seen directly through changes to fish or prey physiology, e.g., metabolism rates, and indirectly by alterations in the amount and quality of available habitat. Increased water temperatures could lead to lower concentrations of dissolved oxygen in the deepest parts of the lake, increased toxicity of pollutants throughout the water column, more algal blooms, longer and stronger thermal stratification, increased penetration of UV-B light which exacerbates the toxicity of some pollutants, and changes in water levels (Ficke et al. 2007, Rutherford et al. 2007), all of which could affect the viability and success of fish stocks. While effects of climate change on specific temperate fishes are not well understood, it is generally accepted that some species or particular life stages will benefit from warmer temperatures while others will suffer (Rutherford et al. 2007). Effects are also expected to vary spatially within a lake, particularly between wetland versus non-wetland habitat and near- versus offshore regions.

Habitat loss comes in many forms, including physical removal of vegetation or destruction of reefs where fishes spawn (sometimes in the form of silt gathering on the reefs). One type of habitat that is not always considered is thermal habitat. Different fish species have different preferred temperatures for growth and survival. If temperatures rise far above a fish's critical maximum, their ability to function deteriorates and they may not survive or reproduce. Similarly, if temperatures are too cold a given fish species may not be able to survive. Climate change may result in drastic enough changes to Lake Michigan that some species cease to thrive while others flourish.

Several of the important fishes of Lake Michigan, e.g., whitefish, lake trout, yellow perch, are cool or cold water species, which tend to seek refuge in the hypolimnion during the warm summer months (Ficke et al. 2007). Any changes to the size, temperature or duration of stratification (and the thermocline and hypolimnion) will likely affect their growth, reproduction and survival.



At the same time, some warmer water species such as yellow perch and smallmouth bass may see improved growth and reproduction in response to changes in water temperature. Larvae of prey species such as alewife, bloater and rainbow smelt also respond to changes in temperature (Rutherford et al. 2007), and research suggests that the effects of climate change may cause individuals of these species to concentrate around the thermocline rather than spread themselves throughout the water column (Ficke et al. 2007). Changes in the distribution of prey within the water column will no doubt affect the distributions of predators (Hrabik et al. 2006), which would in turn affect the ability of anglers and fishers to catch species of interest.



While the ultimate outcome of changes in temperature values of Lake Michigan, including how great the difference is between "warm" and "cool" water and how long the stratified period will last, are not completely known, we know enough about species' life histories to predict which species will benefit and which will not.

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Fish species in Lake Michigan (lake proper):

Most common

- Alewife
- Chinook salmon
- Coho salmon
- Brown trout
- Steelhead (rainbow trout)
- Freshwater drum
- Lake Trout
- Round Goby
- Spottail shiner
- Yellow perch
- Lake white fish
- Gizzard shad
- Sea Lamprey
- Channel catfish

Less common

- Walleye
- White and Long nose sucker
- Red horse
- Rainbow smelt

Appendix C.

Fish species in Lake Michigan Basin (area from the light house to the mouth of trail creek up to the sewage disposal discharge):

The basin has its own unique characteristics compared to the lake itself and Trail Creek. The Washington Park Marina, the Bluechip Marina, and the sewage plant discharge provide habitat for different fishes. Channelization and manmade structures also create unique niches for fish.

Most Common

- Small and Large mouth bass
- Carp
- Black and White crappie
- Sunfish
- Rock bass
- Freshwater drum
- Round Goby
- White sucker
- Bullhead and Channel catfish
- Gizzard shad

Less common

- Northern pike
- Northern Quillback
- Goldfish
- Walleye
- Buffalo
- Bowfin

Fish species in Trail Creek (river):

Most Common

- Creek chub
- Sunfish
- Golden shiner
- White suckers
- Round Goby
- Mottled sculpin
- Steelhead (rainbow trout)
- Coho Salmon
- Chinook Salmon
- Bullhead catfish
- Crayfish

Less Common

- Brown Trout
- Northern pike
- Smallmouth bass
- Largemouth bass

Lake Michigan by the Numbers

Grades 6-12

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– *Margaret Mead*

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