   

**Project EDDIE: LAKE ICE PHENOLOGY**

**Student Handout**

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Learning objectives:

* Understand how global climate change impacts local aquatic ecosystems
* Analyze a long-term ice-off dataset with understanding of statistical differences, biological relevance, and sources of variation
* Predict future scenarios of ice-off using linear models
* Develop basic skills using Excel for graphing and statistics
* Calculate lake heat budgets, and understand the interactions between lake ice-off date and heat storage

Why this matters: Lakes are changing worldwide due to altered climate. Many lakes that were historically frozen in the winter are now experiencing fewer days of ice cover and earlier ice-off dates. In this module, you will explore long-term ice-off datasets from several lakes and use linear regression to make predictions about ice-off dates in the future.

Outline:

1. Discussion of papers read for class and quick PowerPoint introduction
2. Activity A: Introduction to regression
3. Activity B: Segmented regression and prediction
4. Activity C: Implications of ice-off for lake heat budgets

Required pre-class reading:

* Seidl, A. 2009. “Water,” Pages 69-87 in *Early Spring* (Beacon Press, Boston).
* Magnuson, J.J. et al. 2000. Historical Trends in Lake and River Ice Cover in the Northern Hemisphere. *Science* 289: 1743-1746.
* Winder, M. and D.E. Schindler. 2004. Climate change uncouples trophic interactions in an aquatic ecosystem. *Ecology*. 85: 2100-2106.

**Activity A:** Introduction to regression

1. With a partner, construct a regression line describing the relationship between time (year) and ice-off day for a lake chosen from the Excel dataset.
2. Using your regression equation, predict what the ice-off day will be this year.
3. Examine the variation in the regression line over time: how confident are you in your future predicted ice-off date?
4. Compare your lake’s ice-off trends with the rest of your class: how did your lake’s regression line slope compare with the other lakes?
5. Refer to the lake metadata below and discuss how some lake characteristics may have affected ice-off patterns among lakes.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Lake Name** | **Location** | **Latitude** | **Lake area (km2)** | **Trophic status** |
| Baikal | Siberia, Russia | 53 oN | 31,722 | Oligotrophic |
| Cazenovia | Near Syracuse, NY, USA | 42 oN | 4.5 | Eutrophic |
| Mendota | Madison, WI, USA | 43 oN | 39 | Eutrophic |
| Monona | Madison, WI, USA | 43 oN | 13 | Eutrophic |
| Oneida | Near Syracuse, NY, USA | 43 oN | 207 | Mesotrophic |
| Sunapee | Central NH, USA | 43 oN | 17 | Oligotrophic |
| Wingra | Madison, WI, USA | 43 oN | 1 | Eutrophic |

**Activity B:** Segmented regression and prediction

1. Make a figure of the ice-out data for your lake (copy from Excel and paste into Word) and include a descriptive 1-2 sentence figure caption. Rather than using a regression line that spans every year in the dataset, create 2 separate regression lines: one for the earliest data-point through 1970, and the second for 1970 through the most recent data-point.
   1. Writing a concise figure caption is an important scientific skill. Peruse scientific literature for examples of figure captions, such as the Magnuson et al. 2000 paper. Important notes: Be brief! The first sentence of the caption can also be considered a title. If you use abbreviations in the axis label, you must define it in caption. Do not include the ‘why’ in a figure caption; only describe the ‘what.’
2. Respond to the following questions with short answers (1-2 sentences).
   1. What is the average ice-off day-of-year (round to the nearest day) at the first and last year of your dataset? (This is not necessarily the ice-off date listed for the first year in the dataset. Use the regression equation to calculate this: fill the year into the regression equation as the X variable to learn the precise Y ice-off day).
   2. How do the 2 regression lines vary, and why?
   3. What is the predicted ice-off day for your lake in 2050? If you were to report this prediction to a lake manager, what caveats about this prediction would you also provide?

**Activity C:** Implications of ice-off for lake heat budgets

If you want to calculate a lake’s heat budget for a particular year, you must be able to measure the heat storage of the entire water body at a specific point of time. The easiest way to do that is 1) to divide the lake into layers of some chosen thickness, 2) measure the area and average temperature of each layer, 3) multiply the area of a layer by its thickness to find the volume, and 4) multiply the layer’s volume by its temperature to determine its average heat content. Once each layer’s heat content is calculated, sum all of the layers to determine how much heat is stored in the lake at a particular period of time.

For this assignment, I chose real thermal data collected on Mirror Lake, New Hampshire, USA on two dates in 1970 (February 21 and May 17) and two dates in 2005 (February 18 and May 18). The main difference between the two years is that the ice-out day in 1970 = 116 (April 26th) and the ice-out day in 2005 = 92 (April 2nd).

Use the worksheet (see below) to calculate the lake’s heat storage on the February and May dates in both 1970 and 2005 and answer the discussion questions.

These data were from:

* Wetzel, R.G., and G.E. Likens. 2000. Limnological Analyses, 3rd edition. Springer Science and Business Media, Inc. New York
* Likens, G.E., and T.C. Winter. 2010. Mirror Lake Thermal Profiles (1981-present). Durham, NH. Hubbard Brook Data Archive [Database]. http://hubbardbrook.org/data/dataset.php?id=83
* Note: the May 18, 2005 thermal profile was interpolated from April and June 2005 sampling dates.

Respond to the following questions with short answers (1-2 sentences):

1. How does the heat capacity of the lake compare between February 21, 1970 and February 18, 2005 (give values in calories)? For May 17, 1970 vs. May 18, 2005?
2. How does heat capacity influence the ice-out date? How does ice-out date influence heat capacity?
3. Compare the heat storage in Mirror Lake in mid-May between 1970 and 2005. Does having an earlier ice-out date weeks before still influence the lake heat storage in May?
4. Give at least 2 ecological implications of earlier ice-out dates for lake ecology.

Heat Budget Calculation Worksheet

Data for Mirror Lake, NH (43oN, 71oW)

1970 ice-out day = 116 (April 26); 2005 ice-out day = 92 (April 2)

Fill in the table to calculate your answers for the homework. Remember that 1oC cm3 = 1 calorie of heat.

|  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Layer depth (m) | Layer thickness (cm) | Average area of layer (cm2) | Layer volume (cm3) | Average temp. of layer  Feb 21, 1970 (oC) | Heat content per layer on Feb 21, 1970  (oC cm3) | Average temp. of layer May 17, 1970  (oC) | Heat content per layer on May 17, 1970  (oC cm3) | Average temp. of layer  Feb 18, 2005 (oC) | Heat content per layer on Feb 18, 2005  (oC cm3) | Average temp. of layer  May 18, 2005 (oC) | Heat content per layer on May 18, 2005  (oC cm3) |
| 0 | 100 | 1500000000 |  | -4.7 |  | 15.5 |  | 0.3 |  | 17.8 |  |
| 1 | 100 | 1360000000 |  | 3.4 |  | 14.5 |  | 3.9 |  | 17 |  |
| 2 | 100 | 1240000000 |  | 4.2 |  | 13.6 |  | 4 |  | 15.4 |  |
| 3 | 100 | 1150000000 |  | 4.2 |  | 12.2 |  | 4 |  | 13.4 |  |
| 4 | 100 | 1050000000 |  | 4.2 |  | 9.7 |  | 4 |  | 11.7 |  |
| 5 | 100 | 990000000 |  | 4.2 |  | 8.5 |  | 4 |  | 9.5 |  |
| 6 | 100 | 900000000 |  | 4.3 |  | 7.1 |  | 4 |  | 8.1 |  |
| 7 | 100 | 680000000 |  | 4.4 |  | 6.2 |  | 4.1 |  | 7.4 |  |
| 8 | 100 | 320000000 |  | 4.5 |  | 6.1 |  | 4.3 |  | 1.7 |  |
| 9 | 100 | 160000000 |  | 4.7 |  | 5.5 |  | 4.5 |  | 6.6 |  |
| 10 | 100 | 60000000 |  | 5.0 |  | 5.6 |  | 4.6 |  | 6.4 |  |
| 11 |  | 0 |  | 5.3 |  | 5.8 |  | 4.8 |  | 6.4 |  |
| SUM | | | | |  |  |  |  |  |  |  |

Data from Wetzel and Likens (2000) and the Hubbard Brook LTER (Likens and Winter 2010).