Using Water Quality Data

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Note: there are links in this document that will open if you have an active Internet connection.

Introduction

The Grand Valley State University Robert B. Annis Water Resources Institute (AWRI) operates the research and education vessels as part of its Water Resources Outreach Education Program. Aquatic science has been an integral part of the academic program at Grand Valley State University since the 1960s. The *D.J. Angus* and *W.G. Jackson* vessels are well equipped floating laboratory-classrooms used to study the aquatic environment of Lake Michigan and adjoining waters. Educational data sets have been generated throughout the years of operation by students age 9 and up.

An underlying theme of the cruises aboard the vessels is to compare and contrast Lake Michigan with another water body. Lake Michigan has a surface area of about 22,300 square miles making it the third largest Great Lake. In contrast, Spring Lake's surface area is about 1,300 acres with inputs of water mainly through springs, streams, and precipitation. Spring Lake is connected to the Grand River. Muskegon Lake is 4,149 acres in size and it receives flow from the Muskegon River as well as tributaries such as Ryerson and Ruddiman Creeks. To learn how to arrange to take your students on an educational cruise, go to http://www.gvsu.edu/wri/education/, AWRI's education webpage.

The Data

If the students have collected enough of their own data to evaluate water quality, using that data will likely be most interesting to the students. Otherwise, water quality data is available at the Grand Valley State University (GVSU) Annis Water Resources Institute (AWRI) education web page (Water Data). Students collected the data archived there while on cruises aboard GVSU's *D.J. Angus* (Lake Michigan off Grand Haven, Michigan, and the nearby Grand River and Spring Lake) or the *W.G. Jackson* (Lake Michigan off Muskegon, Michigan, and the nearby Muskegon Lake and Muskegon River).

If you elect to use AWRI's data set you should familiarize yourself with the station locations by finding them on the attached maps (Grand River and Spring Lake, Figure 1; Muskegon River and Muskegon Lake; Figure 2). The various sampling locations are noted on the maps. The drainage basin for the Grand River (Grand River Watershed Map), the longest river in Michigan, includes both agricultural and urban areas in its approximately 5,500 square mile drainage area. Spring Lake, a spring-fed, drowned river valley, enters the Grand River approximately 2½ miles from the river's mouth at Lake Michigan. The Lake Michigan shoreline in this area is lined with sand dunes, some over 100 feet high. The Grand Haven/Spring Lake/Ferrysburg area is largely residential and becomes a tourist mecca in the summer months. Spring Lake itself is heavily developed, largely with private homes. In contrast to the Grand River, the area encompassed by the Muskegon River's drainage basin (Muskegon River Watershed Map) is much less (2,723 square miles.) and much less developed. It empties into Muskegon Lake, a deep-water harbor largely surrounded by development. The Lake Michigan shoreline in the Muskegon area is also lined with sand dunes, again some over 100 feet high.

You can download the AWRI data files as an Excel spreadsheet following the directions at: (Water Data). Students can then make plots and manipulate the files directly, or you can give them a subset of the data and ask them to make plots by hand, depending on the goals of the exercise. Additional data sets are available upon request (vailj@gvsu.edu).

Exercise 1: Analyzing Water Quality Data Using X-Y Plots

Students can analyze water quality data by making plots using a variety of parameters (e.g., turbidity, secchi depth, pH, conductivity, dissolved oxygen) for the x and y axes. (To learn how these and other analyses are made and what each indicates about water quality go to Manual By making such plots students will not only become more familiar with the data, but they will become more proficient at plotting numbers (by hand or with a computer), learning the usefulness of such plots, and getting a feel for how scientists analyze large data sets. Importantly, such an exercise will help students appreciate the vital role mathematics plays in science.

Before making the assignment discuss positive and negative correlations and what they indicate. Equally important, discuss what a lack of correlation ("shotgun pattern") indicates. Also discuss "suspect data", data that is inaccurate due to human or machine error. Discuss how x-y plots may help spot suspect data (e.g., all data may fall on a "line" except for one or two data points). For their plots the students might use a different color for each water body (e.g., Lake Michigan, Spring Lake, Grand River) and different symbols (circles, triangles) for the various water depths (top, bottom). For ease of grading, you might ask all students to use the same color and symbol scheme for each plot made.

Also discuss with the students in some detail the data that is to be plotted. Explain that the water in the epilimnion and hypolimnion should be thought of as two separate water masses (see "Seasonal Lake Stratification"). Therefore, lumping data from top and bottom water together (e.g., to obtain a mean value) is normally not a valid exercise. If data is available for a river plume, discuss how that data might be treated. For example, if AWRI data is used, you might see data listed as "Lake Michigan" for the "Body of Water", but designated as "Grand Haven Plume" under "Area". That means that although the station was physically located in Lake Michigan, if the sample was taken from the "top", it likely is Grand River water. However, if the data is from the "bottom", it may be lake water. A class discussion can determine if, for plotting purposes, that data will be treated as lake data, river data, or, as a special category, "plume" data (see "The River Plume"). You should also examine the data set you plan to use to see if you think it contains "suspect data", data that is inaccurate due to human or machine error. Again, you can hold a class discussion and talk about when a scientist is justified in omitting a piece of data during data analysis.

The Plots

The students can make several plots and determine if they see relationships between the various parameters. You might choose different plots for them to make, both those that do and those that do not show relationships. For example, secchi depth and turbidity should show a relationship (although not a linear one) as might conductivity and turbidity, but conductivity and dissolved oxygen probably will not show a relationship. After the students have made plots that you suggest, you might ask them to make a plot using two parameters that they are interested in examining.

Example exercise

1. If you were to make a plot of conductivity versus turbidity, do you predict you would see a relationship? If so, do you predict the relationship would be positive or negative? Explain your reasoning for your prediction.

2. Now make a plot of conductivity (y-axis, numbers should increase up) versus turbidity (x-axis, numbers should increase to the right). Use a different color for each body of water (Lake Michigan, Spring Lake, Grand River), different symbols for water depths (top, bottom), and include a key. Be sure to label the axes and indicate the units.

3. Do you observe a relationship? If so, is it positive or negative? Is it linear? If it is, derive an equation for the "best fit" line through the points. How can such an equation be used as a predictive tool? State in words what the distribution of the data tells you about conductivity and turbidity for these stations (i.e., explain why the data plot as they do).

4. Do data for the different water bodies plot in different areas of the graph? If so, explain why that might be the case (i.e., explain why conductivity and turbidity might be relatively high or low in the various water bodies).

5. Based on your plot do you believe any of the data is "suspect" (inaccurate due to human or machine error)? Explain.

6. If your task was to interpret the data for conductivity and turbidity, which would be easier to interpret, the data in table form, or the data plotted on the x-y plot such as the one you made? Explain your reasoning.

Exercise 2: Analyzing Water Quality Data Using Computation Sheets

Students can evaluate water quality in a very limited sense by investigating analyses of a single parameter (e.g., secchi depth, turbidity, color, pH, conductivity, or dissolved oxygen) or in more detail by considering such parameters collectively. This lesson plan introduces a simple method to help students accomplish the latter. (To learn how these and other analyses are made and what each indicates about water quality, go to Manual.)

You will need to hold a class discussion concerning the data that is to be analyzed. Explain that the water in the epilimnion and hypolimnion should be thought of as two separate water masses and that these water masses likely have different values for many of the parameters measured (see "Seasonal Lake Stratification"). Therefore, on the "Water Quality Computation Sheet" below, top and bottom water are listed separately. If data is available for a river plume (see "The River Plume"), discuss how that data might be treated. For example, if AWRI data is used, you might see data listed as "Lake Michigan" for the "Body of Water", but designated as "Grand Haven Plume" under "Area". That means that although the station was physically located in

Lake Michigan, if the sample was taken from the "top", it likely is Grand River water. However, if the data is from the "bottom", it may be representative of lake water. A class discussion can determine if, when filling out the Computation Sheets, that data will be treated as lake data or river data, or if that data should be omitted for this particular analysis. Alternatively, after discussing the unique situation presented by the plume data, you could let each student decide how to handle that data. (See question 2 below under "Example Exercise".)

Oligotrophic → mesotrophic → eutrophic

Determining water quality is complex; many parameters go into its determination. Evaluation of water quality depends on the designated use of the water. For examples, "good" water quality for warm water fishes may not be "good" water quality for human consumption. Overall water quality can be evaluated by considering the trophic status or biological productivity. Eutrophication, or aging of lakes, progresses through various trophic states (oligotrophic → mesotrophic → eutrophic). Nutrient levels, organic matter content, dissolved oxygen levels, and water transparency give clues to the trophic state or biological productivity of a water body. A trophic scale has been specially designed for use on the vessels. By evaluating data from various parameters, sampling locations are rated as O (oligotrophic), M (mesotrophic), or E (eutrophic).

Oligotrophic lakes are characterized by low nutrient levels, low biomass, high oxygen concentrations, and high transparency. Oligotrophic lakes are usually deep. Eutrophic lakes are highly productive with high nutrient levels, high biomass, low oxygen concentration in the bottom waters, and low transparency. The large volume of organic matter accumulated in bottom sediments depletes oxygen as it decomposes. Mesotrophic lakes are between the other two trophic states in their characteristics. The open waters of Lake Michigan are oligotrophic and some nearshore areas are mesotrophic.

Carlson's trophic status index concept is used by the MDEQ to assess and classify 730 of Michigan's public access lakes. This classification system is based on an index derived from a combination of 3 field measurements: Secchi disk transparency, total phosphorus concentration, and chlorophyll a concentration. The numerical value of the index increases as the degree of eutrophication increases.

Table 1. Trophic Status Summary of Michigan's Public Access Lakes

Trophic Status	Number of Lakes	Acres
Oligotrophic (low nutrients)	118 (16%)	164,595 (33%)
Mesotrophic (moderate nutrients)	386 (53%)	200,651 (40%)
Eutrophic (high nutrients)	196 (27%)	121,046 (24%)
Hypereutrophic (excessive nutrients)	30 (4%)	16,697 (3%)
Total Assessed	730	502,989

Many lakes with moderate to high nutrient levels are located in the southern Lower Peninsula where large population centers and fertile soils exist. Many lakes with low nutrient levels are located in the northern part of Michigan's Lower Peninsula where the population density is lower, soils are less fertile, and lakes tend to be larger and deeper (MDEQ 305b Report, 2006).

The Computation Sheets

This exercise uses a computation sheet modified from that originally developed by Gus Unseld, III as a simple means by which students can estimate water quality. To obtain a valid estimate, the students should use data from numerous stations, probably at least 10 for each water body examined. One sheet should be used for each water body (e.g., Lake Michigan, Spring Lake, or Muskegon Lake). The student simply looks at each piece of data for the water body and makes a mark in the appropriate spot on the sheet. In the end, a number of marks may be made for a particular range for a certain parameter (e.g., the 7.2-8.5 range for pH for top water may have a number of marks).

After working through all the data, the student separately adds up the number of marks for the “green” column, the “yellow” column, and the “red” column. The colors suggest whether or not the data for that parameter is estimated to represent good (oligotrophic) or poor (eutrophic) water quality, or something in between (mesotrophic). The student then does the calculations as indicated at the bottom of the sheet and determines if the lake has relatively good or relatively poor water quality based on the data used in the calculation. You should stress to the students that the calculations they do are based on a relatively small data set. Results for a large lake like Lake Michigan might vary considerably if more data were included. A good class discussion might involve how the results would likely vary if more data were included for Lake Michigan from areas far offshore. Remind the students that most of the data for Lake Michigan included in the calculations are from areas relatively close to shore, which probably greatly affects the analysis.

If you obtain data for this exercise from the AWRI database, it will not contain “sediment” data. In that case, you will need to ask your students to ignore the category for “sediments”. If you have your own sediment data, or data from a database that includes a description of the sediment, you can include it in the calculations. In any case, the “sediments” category is the most difficult to evaluate as the data is not quantitative. If the sediment is primarily clean (little or no organic debris) sand or clean sand and gravel, the mark should be in the “green” column. Sediment in the shallow waters of Lake Michigan typically falls in this category. If the sediment is coarse (sand and/or gravel), but contains significant amounts of organic material such as wood, bark, or leaves, the mark should be made in the “yellow” column. Commonly, but not always, sediment from the Grand River falls in this category. Finally, if the sediment is ooze, it falls in the “red” column. Ooze is defined herein as fine grained sediment (silt and/or clay) with abundant, very fine, organic material. The organic debris usually can not be identified as such in the field, but it typically will result in the sediment being a black or dark greenish gray color. When first collected it may have a rotten egg smell due to the decay of organic matter by anaerobic bacteria. Most of the sediment in Spring Lake is ooze.

You will need to carefully explain to the students how to fill out the computation sheets. Be sure to provide the students with one sheet for each of the water bodies to be evaluated (e.g., one sheet for Lake Michigan, one for Spring Lake, etc.). To clarify the procedure for the students an overhead of an example computation sheet helps.

<u>Example exercise</u>

1. Before estimating the health of each of the water bodies, predict what you think the outcome of your calculations will be for each (e.g., will Lake Michigan be found to have good water quality or poor water quality?). Explain your reasoning.

2. Fill out the computation sheets. Please note whether or not you included the plume data and explain your reasoning.

3. Were you surprised by any of the results of your calculations? Did you correctly predict the water quality for each of the water bodies? Do you believe the results, or do you think the calculations themselves are questionable?

4. For each water body discuss which parameters (e.g., pH, conductivity, etc.) appear to be doing the most harm to the overall, calculated water quality.

5. What do you predict for the future of each of the water bodies? For example, for which do you expect water quality to improve? Get worse? Explain.

6. Assume that you are in the state legislature and write a proposal that will improve the health of Lake Michigan and inland lakes. In writing your proposal be sure to consider your answers to numbers 4 and 5 above and the results of your computation sheets. Do you think your proposal could pass and become law? Explain.

Sources:

Living with the Great Lakes Dr. Patricia E. Videtich http://faculty.gvsu.edu/videticp/

GVSU Annis Water Resources Institute http://www.gvsu.edu/wri/education

WATER QUALITY COMPUTATION SHEET

	GREEN	YELLOW	RED
secchi disk	___ ≥ 5.0 m	___ 2.0 to < 5.0 m	___ < 2.0 m
color	___ 1 to 9	___ > 9 to 16	___ > 16
turbidity			
top	___ ≤ 1.0 NTU	___ > 1.0 to 3.0 NTU	___ > 3.0 NTU
bottom	___ ≤ 1.0 NTU	___ > 1.0 to 3.0 NTU	___ > 3.0 NTU
conductivity			
top	___ ≤ 250 μmhos	___ > 250 to 500 μmhos	___ > 500 μmhos
bottom	___ ≤ 250 μmhos	___ > 250 to 500 μmhos	___ > 500 μmhos
temperature			
top	___ $\leq 20^{0}$ C	___ $>20^{0}$ C, but $\leq 24^{0}$ C	___ $>24^{0}$ C
bottom	___ $\leq 10^{0}$ C	___ $>10^{0}$ C, but $\leq 14^{0}$ C	___ $>14^{0}$ C
dissolved oxygen			
top	___ ≥ 8 ppm	___ 4 to < 8 ppm	___ <4 ppm
bottom	___ ≥ 6 ppm	___ 3 to < 6 ppm	___ <3 ppm
% saturation			
top	___ 89% to 111%	___ 66 to < 89 % or > 111-130%	___ < 66% or > 130%
bottom	___ 89% to 111%	___ 66 to < 89% or > 111-130%	___ < 66% or > 130%
pH top	___ 7.2 to 8.5	___ 6.5 to <7.2 or >8.5 to 9.0	___ < 6.5 or > 9.0
bottom	___ 7.2 to 8.5	___ 6.5 to <7.2 or >8.5 to 9.0	___ < 6.5 or > 9.0
sediments	___ sand &/or gravel	___ sand & organics (wood, bark, leaves)	___ ooze (fine, organic rich clay &/or silt)

\# of greens ___ X 3 = ____________

\# of yellows ___ X 2 = ____________ $\frac{b}{a}$ = ___ =

\# of reds ___ X 1 = ____________

total = ___ (a) ____________ (b)

green = 2.3 to 3.0 (good water quality)

yellow = 1.7 to < 2.3 (intermediate)

red = 0.0 to < 1.7 (poor water quality)