A Study of Water Quality of Lakes in Rice and Scott Counties, MN

Mike Ahlin
Nathan Kennedy
Ali Reingold
Nina Schwartz

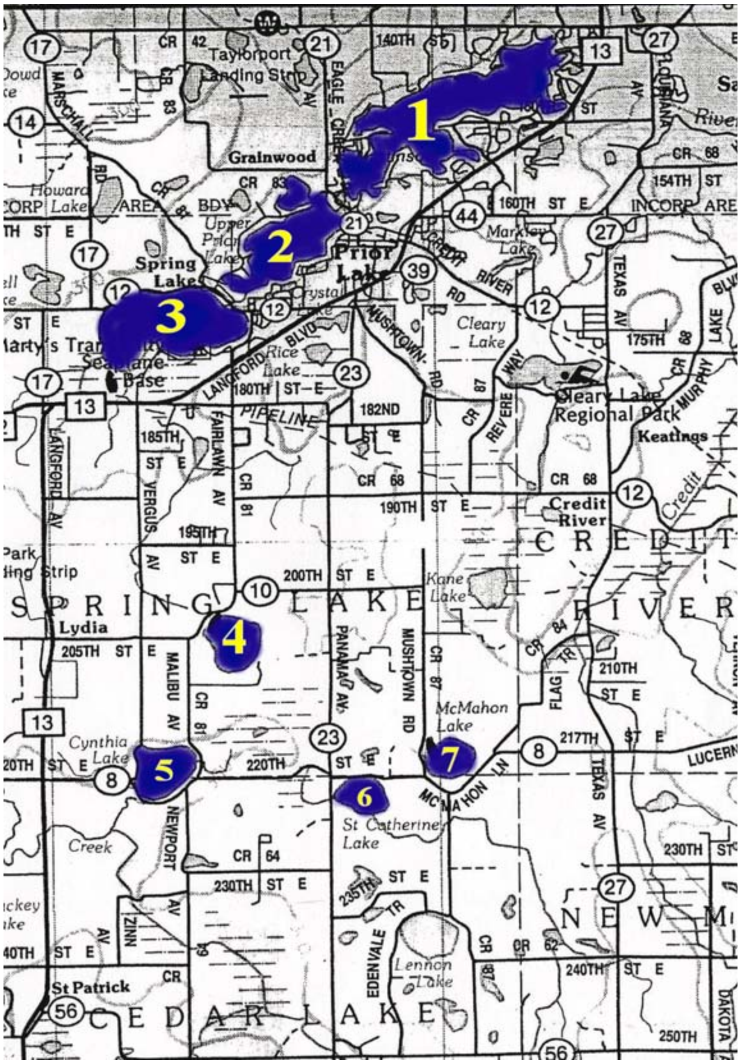
Carleton College
Environmental Geology 120
Fall 2004

Introduction

Lakes in Rice and Scott Counties in southern Minnesota have had relatively strong water quality records for the past decade. Data from the Minnesota Pollution Control Agency (MPCA) indicate that several lakes in Rice and Scott Counties recently possessed an average turbidity between 1 and 2 meters, an average alkalinity of approximately 120 to 160 ppm, and an average phosphorus content of 27 to 375 ppb (MPCA). However, seasonal variation and location cause differences in water quality data, especially with turbidity, dissolved oxygen content, temperature, and phosphorous and nitrogen levels (PCA). The goal of this project was to sample water from lakes in Rice and Scott counties (Figure 1) and compare it to other data by analyzing how the surrounding environment influences their differing water qualities. Assessing information on the temperature, turbidity, and dissolved solids of lake water yielded explanations to the role of location, agricultural farm treatments, and residential surroundings in causing fluctuations in lake water quality.

Rice and Scott counties, located about 25-50 miles south of the Twin Cities, are mainly rural, with populations of approximately 57,000 and 90,000, respectively. The land surrounding the majority of lakes sampled is agricultural, and used mainly for harvesting wheat barley, corn, and hay (MN Agricultural Statistics Service). Grassy fields, wetlands, and other undeveloped lands are common lake surroundings. However, a few lakes in these counties such as Upper Prior, Lower Prior and Spring Lake (Figure 1), are located in residential areas and, judging by the large number of boat docks, are often used for recreation. These three are close to high densities of main roads and large suburban areas.

Testing water quality is important, because contaminants in the water may lead to disease or other negative effects. High levels of nitrate and nitrite, caused mainly by fertilizers, can lead to blue baby disease in infants. Sulfate, largely a result of animal sewage and industrial waste, causes corrosion and is characterized by a bitter taste and a rotten smell. Excessive amounts of chloride, also caused by animal sewage and from road salt, corrode pipes and lead to high blood pressure in humans (EPA). Lakes containing high levels of these chemicals should be cleaned so that these effects are not realized.



Lakes Sampled:
1) Lower Prior Lake
2) Upper Prior Lake
3) Spring Lake
4) Fish Lake
5) Cynthia Lake
6) St. Catherine Lake
7) McMahon Lake
8) Lake Sanborn
9) Rice Lake
10) Phelps Lake
11) Duban Lake

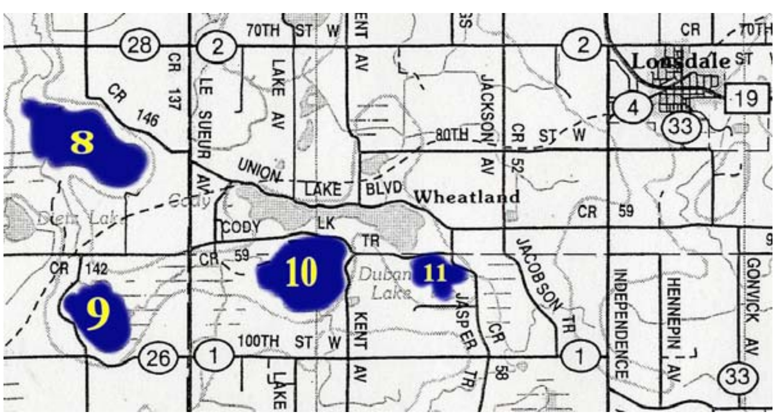


Figure 1. Locations of the lakes sampled in Scott (top) and Rice (bottom) Counties.

Materials & Methods

Over the course of four trips to the field between October 5 and October 26, 2004, our group recorded water quality data from eleven lakes in Scott and Rice counties. We measured the water temperature (^{o}C), turbidity (cm), salinity (ppt), conductivity (µs), and dissolved oxygen content (mg/L). Temperature, salinity, conductivity, and dissolved oxygen content were taken with a Model 85 Yellow Springs Instrument (YSI meter) from an average distance of 2-3 feet from the water's edge of each lake. The YSI meter took two conductivity readings, adjusting the second reading for the lake's temperature. Turbidity was taken with a Secchi tube, in which water was filled to the brim (122 cm) then slowly released until the Secchi disk was clearly visible. The turbidity reading reflects the water level in the tube at the point at which the Secchi Disk is first clearly visible, indicating the relative clarity, or light penetration of the water.

Each data category was consistently recorded at all lakes except for dissolved oxygen readings. Due to complications with the YSI meter, dissolved oxygen contents were not taken for Lakes Cynthia, Fish, McMahon and St. Catherine.

After all the samples were taken, they were analyzed in the lab for chloride, sulfate, nitrate, nitrite, and phosphate. This was done with an ion chromatograph, in which the different anions are separated based on their retention time in a low capacity, strongly basic anion exchanger. The separated anions are then passed through a highly acidic cation exchanger, which converts the anions to their more conductive acid forms. The identities of the anions are determined by their retention times, and the amounts of each are found by measuring the conductivity of the acidic forms.

Our team also photographed the shores and water at each location, which illustrate the differing surrounding environments that helped shape the individual characteristics of each lake's results; run-off from a nearby farm, for example, may contribute to increased levels of nitrates or phosphates, while a surrounding residential neighborhood may have a different effect on a lake's health. Water readings and samples from all lakes were taken from the shore, except for Lake Sanborn, where samples were taken from the edge of an approximately 12 ft. boardwalk extending into the lake.

Results

On October 5, 2004 our group gathered field samples and data from Lakes Duban, Phelps, Rice, and Sanborn. The water in Duban Lake was 13.7 degrees Celsius, and had a relatively murky turbidity of 10.5 cm. The salinity was 0.2 ppt, which held true for the other three lakes we visited that day. Duban Lake's conductivity measured 293 µs, and dissolved oxygen measured 10.65 mg/L.

Phelps Lake had a temperature of 13.2 degrees Celsius. The water was extremely hazy with a turbidity of only 9 cm. The salinity was 0.2 ppt. Conductivity was first measured at 266.5 µs, and the second reading indicated a conductivity of 345.2 ppt. The dissolved oxygen measured 9.02 mg/L.

Rice Lake had the lowest temperature of the October 5^{th} lakes at 12.2 degrees Celsius. This clear, residential lake had a turbidity of 29 cm, far exceeding that of the other nearby lakes. The salinity was 0.2 ppt, and the conductivity ranged from 438.5 µs on the high end down to 332.3 µs. Dissolved oxygen read 7.25 mg/L.

Lake Sanborn was the warmest lake visited on October 5, with a temperature of 15 degrees Celsius. Sanborn's turbidity was 12 cm, and yielded a salinity identical to the other three lakes of 0.2 ppt. Its conductivity had a similar range as Rice Lake, decreasing from 343 μs to 426 μs at its second reading. The dissolved oxygen recorded was the lowest oxygen reading of the day, falling at a paltry 4.87 mg/L.

On October 18th we visited four lakes to the north of the lakes we measured on October 5th. Cynthia Lake had the lowest water temperature of all lakes sampled at a chilly 8.1 degrees Celsius. Its turbidity was 14 cm. Following the common theme of the previous day's readings, Cynthia possessed a salinity of 0.2 ppt. The conductivity ranged greatly from 281.5 μs to 414.4 μs. The temperature of Fish Lake was 10.2 degrees Celsius, and its clear water indicated a turbidity of 43 cm. Fish Lake's salinity measured 0.2 ppt, and conductivity ranged from 279.6 to 390.6 μs. St Catherine Lake had a temperature of 8.3 degrees Celsius. The turbidity was nearly as high as Fish Lake's at 36 cm. Salinity continuously measured 0.2 ppt, and conductivity ranged all the way from 432 μs to 294 μs. McMahon Lake measured 9 degrees Celsius, and indicated a moderate turbidity of 25.5 cm. The salinity measured only 0.1 ppt, making it the first lake not measured at 0.2 ppt. The conductivity was extremely low ranging only from 189.3 μs down to the very low 131.3 μs.

On October 26th, we made our last trip to the field and visited lakes slightly to the North of those studied on October 18th. The temperature of Spring Lake was 10.8 degrees Celsius, and its very clear water had a turbidity of 72 cm. The salinity measured 0.2 ppt, and conductivity ranged from 343 μs to 470.3 μs. The dissolved oxygen was 6.32 mg/L. Upper Prior Lake had a temperature of 9.6 degrees Celsius. The turbidity measured 47 cm, while its relatively high conductivity ranged from 353.6 ppt to 501 ppt. Dissolved oxygen on this lake was the lowest of any we sampled at 4.2 mg/L. Lower Prior Lake had different measurements to Upper Prior, despite their close proximity. The temperature was 11.4 degrees Celsius. Its crystal-clear water had a turbidity so high that it exceeded the 122 cm of the Secchi disk, and possibly extended even higher than that. The salinity measured an unsurprising 0.2 ppt, conductivity ranged from 313.4 µs up to 426.3 µs, and the dissolved oxygen measured 5.7 mg/L.

Table 1. Water Quality Measurements for Selected Lakes. The Temperature, turbidity (correlates to Secchi Depth) salinity, and conductivity were taken for all lakes. Dissolved oxygen readings were only calculated for specific lakes due to technical complications.

	Date visited (2004)	**Temp (^{o}C)**	**Secchi Depth (cm)**	**Salinity (ppt)**	**Conductivity (µs)**	**Dissolved Oxygen (mg/L)**
Duban	10/5	13.7	10.5	0.2	293	10.65
Phelps	10/5	13.2	9	0.2	266.5/345.2	9.02
Rice	10/5	12.2	29	0.2	333.2/438.5	7.25
Sanborn	10/5	15.0	12	0.2	343/426	4.87
Cynthia	10/18	8.1	14	0.2	281.5/414.4	No data
Fish	10/18	10.2	43	0.2	390.6/279.6	--------
St. Catherine	10/18	8.3	36	0.2	432/294	--------
McMahon	10/18	9.0	25.5	0.1	189.3/131.3	--------
Spring	10/26	10.8	72	0.2	343/470.3	6.32
U. Prior	10/26	9.5	47	0.2	353.6/501	4.20
L. Prior	10/26	11.4	122+	0.2	313.4/426.3	5.70

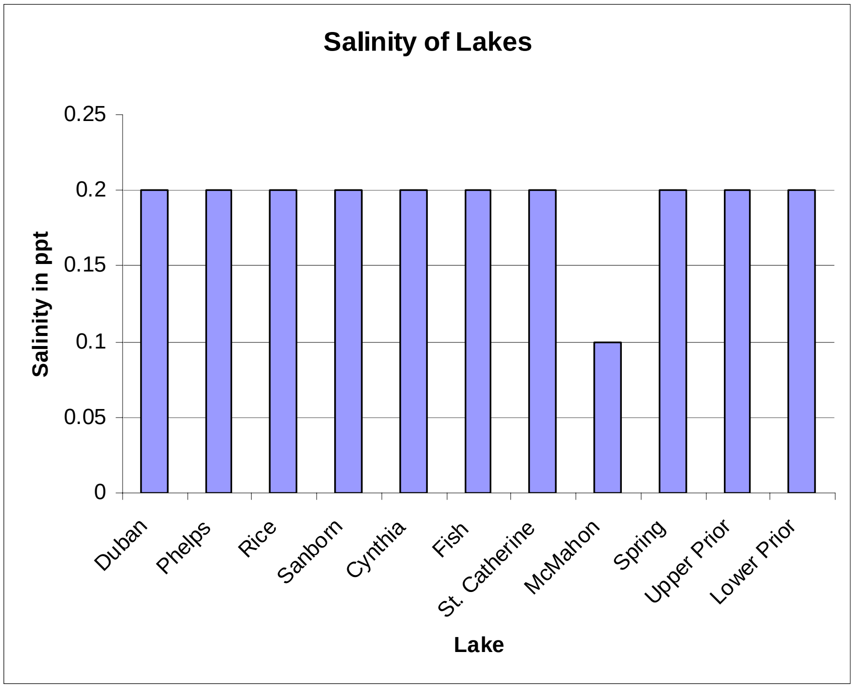


Figure 2. Salinity of lakes tested in Rice and Scott Counties. Salinity readings remained at a constant 0.2, except for Lake McMahon, which had a reading of 0.1

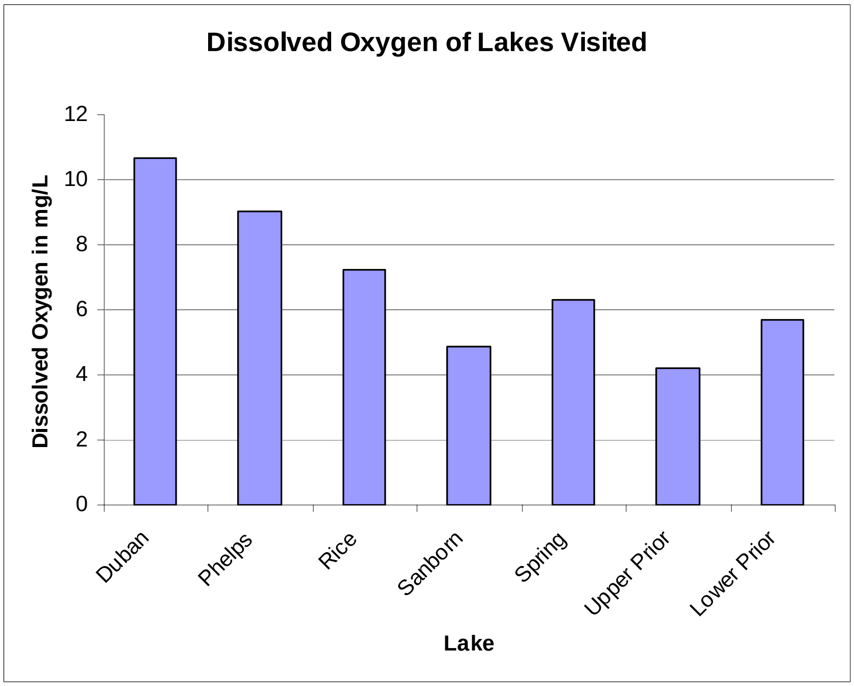


Figure 3. Dissolved Oxygen of Lakes Visited in Rice and Scott Counties. Dissolved oxygen readings were highest for lakes Duban and Phelps and for those in Rice County.

Discussion

Turbidity had an extremely large range of measurements, with the Secchi depth ranging from 9 cm in Phelps to over 122 cm in Lower Prior (Figure 4). The three least turbid lakes were Upper Prior, Spring, and Lower Prior Lakes, with Secchi depths of 47 cm, 72 cm, and 122+ cm respectively. These lakes are located in largely residential areas. Phelps Lake had the worst turbidity of only 9 cm, and the rest of the lakes with similarly low Secchi depths, especially Duban, Sanborn, and Cynthia, are nearer to farmlands. Based on this, we conclude that agricultural practices are somehow affecting the lakes' water quality, and that the residential areas seemed to act as a buffer against agricultural runoff, leading to clearer water and a higher Secchi depth.

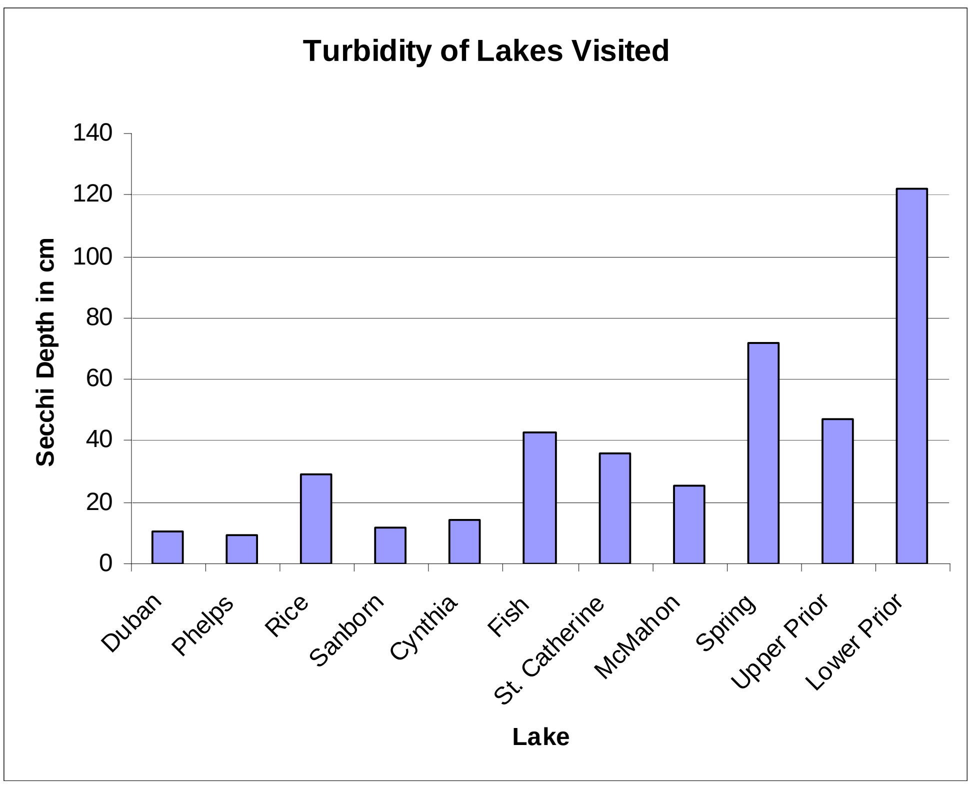


Figure 4. Turbidity of lakes visited in Scott and Rice counties. Turbidity had a wide range of measurements. This graph illustrates that turbidity ranged greatly, and that lakes in residential areas tended to have lower turbidities than those with predominantly agricultural surroundings.

While several of our lakes have higher concentrations of dissolved solids than others, all of the lakes we sampled seem to be relatively clean (Table 2). The Environmental Protection Agency (EPA) places the drinking water standards for sulfate and chloride at a maximum of 250 mg/L, and all of the lakes we visited measured well below this level. The nitrogen readings calculated from nitrite and nitrate for Fish and Sanborn were an identical 0.11 mg/L. While these two lakes were fairly distant in our range of lakes sampled, neighboring lakes such as Upper Prior, Lower Prior, and Spring also yielded similar nitrogen readings, with Spring reading 0.038 and Lower Prior reading 0. This indicates that nitrogen levels are a factor of the surrounding environment. The maximum EPA level for nitrate is 10 mg/L, and that for nitrite is 1 mg/L (EPA). Our samples were well within these EPA standards, so our lakes can be assessed as fairly healthy.

Table 2. Ion Results from Selected Lakes.

	Nitrate	**Nitrite**	**Phosphate**	**Sulfate**	**Chloride**
Duban	1.72	0.15	0	25.26	11.35
Phelps	0.36	0	0	27.67	15.08
Rice	1.30	0	0.39	30.86	25.45
Sanborn	0.49	0.11	0	11.99	16.41
Cynthia	No data	--------	--------	--------	--------
Fish	0.49	0	0	3.95	40.28
St. Catherine	0	0	0.47	13.76	26.64
McMahon	0	0	0	2.03	10.85
Spring	0.17	0	0	13.13	47.06
Upper Prior	No data	-------	--------	--------	--------
Lower Prior	0	0	0	4.75	21.12

The temperature of all lakes tested ranged from 8 to 15 degrees Celsius (Figure 6). Lake temperature is greatly a factor of season and time of day. However, lakes in close proximity with each other, such as lakes Duban, Phelps, and Rice yielded similar readings, which is evidence that temperature might also be a factor of location. However, these similarities in temperature by location are more likely a result of neighboring lakes being tested on the same day, since the air temperatures varied each day we visited the field.

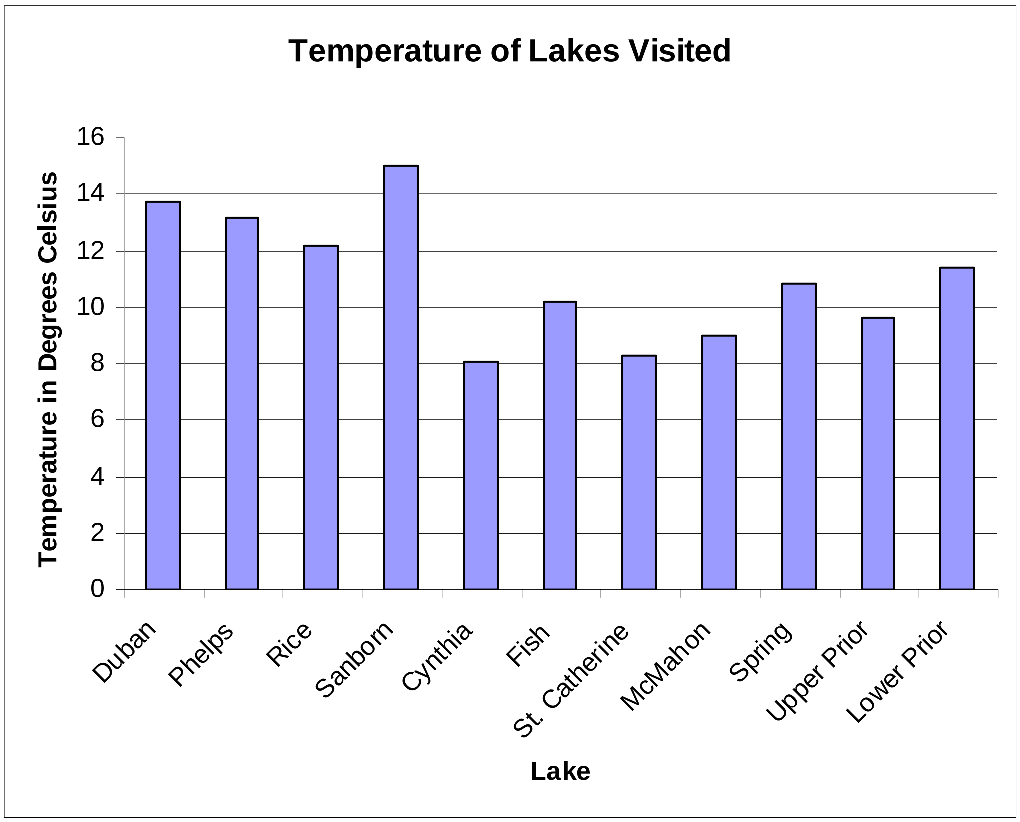


Figure 5. Temperature of Lakes Visited in Rice and Scott counties. Temperature ranged from about 8 degrees Celsius to 15 degrees Celsius.

Birr and Mulla confirm that agriculture impacts water quality, saying that "watersheds with the poorest lake water quality correspond to areas of intense agricultural production relative to the watersheds with lower total phosphate concentrations." The only lake for which we have both phosphate and nitrogen data is Rice Lake, with a phosphate reading of 0.39 and a nitrate reading of 1.30. The only nitrite levels were recorded for Sanborn, 0.11, and Duban, 0.15. Neither of these lakes recorded any phosphate. At the same time, St. Catherine illustrated the highest phosphate reading of 0.47, yet had nitrate and nitrite levels of 0.

According to the Pollution Control Agency (PCA), high phosphorous often corresponds to higher turbidity. Lake St. Catherine had higher phosphate level and turbidity of 0.47 and 36cm, respectively, while Rice Lake had a lower phosphate level and turbidity of 0.39 and 29cm, respectively. While these two lakes do not fit into the pattern noted by the PCA, we lacked adequate phosphate data to make a useful comparison. However, according to the US Department of Agriculture, nitrate is used as a fertilizer in many of the same areas as is phosphorus. If we compare nitrate and turbidity, there is a clear indirect relationship, with the Secchi depth falling as the amount of nitrate increases. This indicates that the farms in the area are affecting the water quality of our lakes.

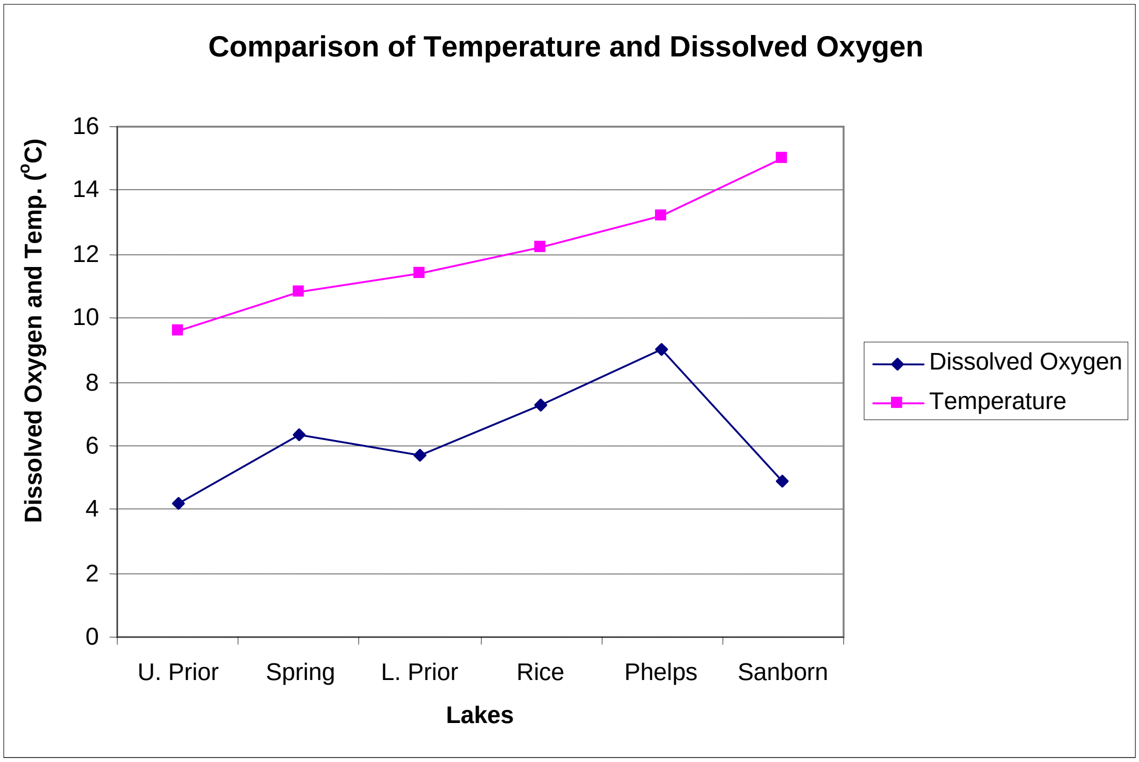


Figure 6. Comparison of Dissolved Oxygen to Temperature in Selected Lakes. Theoretically, warmer water contains less dissolved oxygen than colder water. However, this graph indicates that our lakes do not necessarily fit into that pattern.

In order to give some standard for comparison for our results, we compared certain findings with those of previous groups on the Cannon River, known for its dirty water, and Kelley-Dudley Lake, a good standard for clean water. Most of our lakes were relatively murky, and only two of them were significantly over 40 cm in Secchi depth, while six were under 25 cm. The large exception to this was Lower Prior Lake with a Secchi depth exceeding the 122 cm. In contrast, most of the Cannon River's readings were taken at above 40 cm in Secchi depth, although none were as high as Lower Prior Lake. The Cannon River group took multiple readings from April to May. The readings they took in May were very similar to our findings while those taken in April were significantly higher than ours. The Kelley-Dudley group's turbidity findings, which remained relatively constant through both months, were almost identical to the turbidity of Lower Prior.

The conductivity levels of our lakes ranged from just over 100 ms all the way up to 500 ms (Figure 7). The majority of readings hovered in a range from just under 300 ms to just over 400 ms. Kelley-Dudley had lower findings which didn't rise above 250 ms. In contrast, the Cannon River group's findings were remarkably similar to ours, varying roughly from 300-400 ms. In total, the bodies of water possessing lower turbidity measurements had uniformly higher conductivity measurements, perhaps suggesting an inverse relationship between turbidity and conductivity.

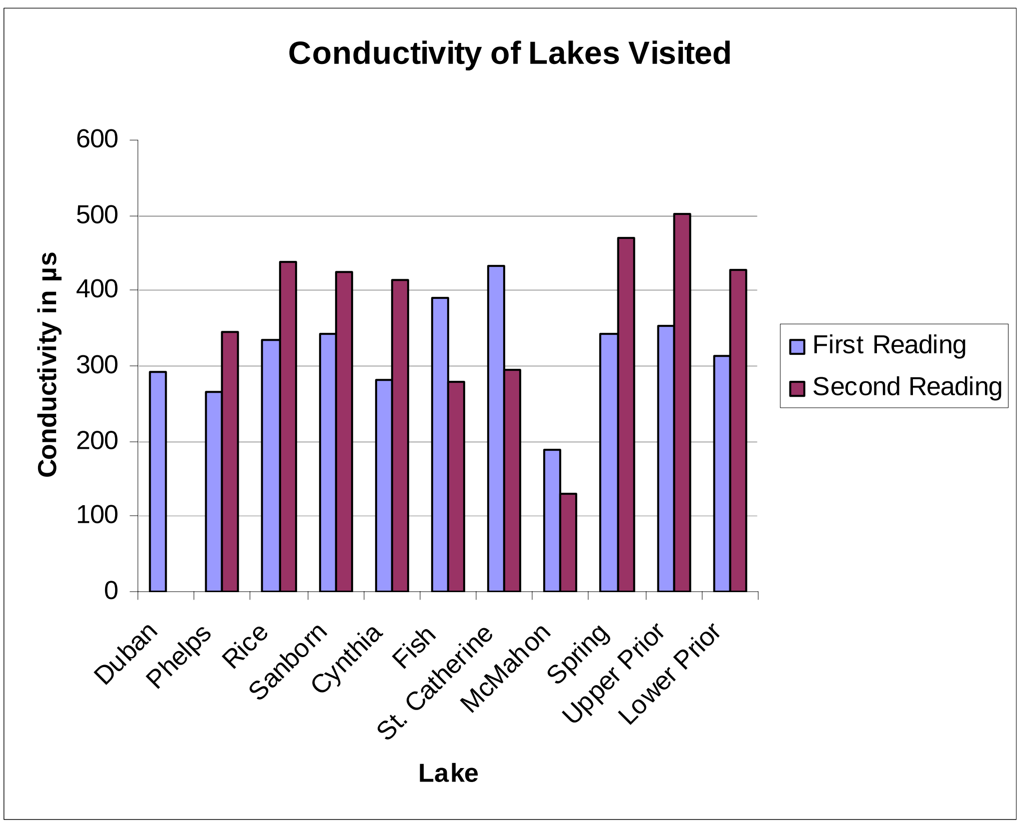


Figure 7. Conductivity of lakes visited in Rice and Scott counties. Conductivity ranged greatly, with Upper Prior, Lower Prior, and Spring Lakes yielding the highest.

Dissolved solids are another critical factor in lake water quality. Our samples yielded nitrate levels that were generally under 1 mg/L, with two lakes between 1 mg/L but under 2 mg/L. The Cannon River found similar nitrate levels, although they had a few readings between 3 and 6 mg/L. Kelley-Dudley had almost nonexistent levels of nitrates. The sulfate levels in our samples generally ranged from 12 to 31 mg/L. The Cannon River group had similar findings, but Kelley-Dudley showed sulfate levels of around 3 mg/L, which was very close to the sulfate level of Lower Prior Lake. Chloride levels in our lakes ranged greatly, with a couple lakes between 10 and 20 mg/L, a couple more from 20 to 30 mg/L, and two over 40 mg/L. Although they had no readings over 40 mg/L, the Cannon River findings once again closely coincided with those of our lakes. Kelley-Dudley showed low chloride levels ranging just under 15 mg/L. While all these levels are within the EPA's standards, based on the comparison with these standards there are clear differences in levels between the lakes our group sampled. Lower Prior and Kelley-Dudley had by far the highest Secchi depths, low levels of conductivity, and also some of the lowest levels of pollutants. Conversely, many of our other sampled lakes and the Cannon River had low Secchi depths, high conductivity levels, and high pollutant levels.

Conclusion

Variations in data led to conclusions about the effects of agricultural maintenance and residential areas on lakes. Lakes in residential areas, such as Lower Prior, Upper Prior, and Spring Lakes had lower turbidities and higher conductivities than lakes in predominantly agricultural surroundings. Higher conductivity contents can be linked to pollution from chemicals used in homes. We believe temperature to be related more to the date when the samples were taken rather than other indicators, since lakes tested on the same day generally yielded similar temperatures, and air temperatures varied on the days we sampled.

Lakes in more agricultural areas, on the other hand, tended to have higher turbidities, which based on our research we believe to be most likely due to agricultural runoff high in nitrogen and phosphorous. Lakes with greater agricultural surroundings, especially Lakes Duban, Rice, and Phelps yielded higher dissolved oxygen readings than residential lakes. Dissolved oxygen is a factor of temperature readings, and is a strong indicator of healthy water because it measures its ability to support fish life. Dissolved readings of about 2 mg/L are considered optimal (geo pamphlet). Even though all lakes sampled yielded oxygen readings above 2 mg/L, the highest dissolved oxygen readings in the agricultural lakes indicate that nitrogen and phosphorous runoff from pesticides are also a factor that decreases water quality.

Other trends became apparent when analyzing dissolved solids data. First, lakes with low Secchi depths tended to have higher conductivity levels, while lakes with high Secchi depths had lower conductivity levels. Also, the lakes with higher Secchi depths had much lower levels of the pollutants nitrate, chloride, and sulfate. Lower Prior seems to be similar to Kelley-Dudley Lake in terms of cleanliness, while many of the lakes further south that we sampled have serious problems with the water quality.

Acknowledgements

We would like to thank Bereket Hailab for his time, enthusiasm, and help with this project, and especially for analyzing our samples in the lab. Also, thanks are due to our two class teaching assistants, Colin and John, for their help with driving us to lakes and interpreting results. Their efforts made the completion of this analysis possible. In addition, we appreciate the use of equipment and materials provided by the Carleton College Geology Department. We appreciate also the other groups who shared their data with us. Finally, we must thank the residents of Scott County, especially the St. Olaf alumnus, who generously allowed us to take samples from their property.

References

Birr, AS and Mulla, DJ. “Evaluation of the Phosphorus Index in Watersheds at the Regional Scale” Journal of Environmental Quality 30: 2018-2025. Water Abstracts Resources. Internet Database Service. Carleton College Library. 23 Sept. 2004. <http://ca1.csa.com/htbin/ids65/procskel.cgi>

“Counties in Minnesota River Basin.” 1 November 2004. <http://www.soils.umn.edu/research/mn-river/doc/county>

“County Estimates - Crops.” Minnesota Agricultural Statistics Service. 1 Nov. 2004. <http://www.nass.usda.gov/mn/cti/crop/htm.>

Environmental Protection Agency (EPA) “Ground Water Quality: Contaminant Sources.” 18 Nov. 2004. <http://www.epa.gov/seahome/groundwater/src/quality2.htm>

Festful, DR. “Water Quality Modeling of a Chain of Lakes in a Rapidly-Developing Suburban Area Using the WERM Model.” James M. Montgomery, Consulting Engineers, Inc., 1990.

“Lake Water Quality Assessment Program.” Minnesota Pollution Control Agency. 1 November 2004. <http://www.pca.state.mn.us/water/clmp/lkwqResult.cfm>

“Minnesota Department of Natural Resources.” 23 Sept. 2004. <http://www.dnr.state.mn.ues/index>

Nelson, Luanne. “Streamflow and water-quality data for lake and wetland inflows and outflows in the Twin Cities Metropolitan Area, Minnesota, 1981-2.” U.S. Dept. of the Interior, Geological Survey 83-545, 1981-2.

Scheffer, M; Rinaldi, S; Gragnani, A; Mur, LR; van Nes, EH. “On the dominance of filamentous Cyanobacteria in shallow, turbid lakes.” Ecology 78: 272-282. Water Abstracts Resources. Internet Database Service. Carleton College Library. 23 Sept. 2004. <http://ca1.csa.com/htbin/ids65/procskel.cgi>

“Watershed Management.” 23 Sept. 2004. Available at <http://www.co.scott.mn.us>