Six Rice County Lakes:
A Study of Winter Water Quality

Winter 2006

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Geology 120

Introduction

Minnesota is commonly referred to as the "Land of 10,000 lakes" since lakes in Minnesota are both valuable resources and a popular sources of entertainment. With increased use, lakes become degraded, polluted, and contaminated if not monitored carefully. Much of the activity occurs during the summer when swimming, boating, and fishing are all common pastimes. As a result particular attention has been paid to examining the impact of humans on Minnesota lakes.

Of particular interest in Minnesota, are the lakes in Rice County since the county is readily increasing in population and farming is heavily practiced. The effects of these two factors likely have a significant impact on water quality of the lakes. Already, previous studies have shown that the water qualities of Rice County lakes are in relatively good condition (Carleton 2003, 2004). In 2003, Rice County lakes were all deemed usable for human use in accordance with Environmental Protection Agency standards (Carleton 2004). Additionally, the Minnesota Pollution Control Agency supported this finding. In the fall of 2004, students from Carleton detected an increase in nitrate and phosphate in the lakes, but there were no signs of advanced eutrophication or pollution.

As of the present time, there is little data on the water quality of Minnesota lakes during the winter. However, we believe that winter water samples can provide important information about the effects and repercussions of humans and natural processes as well. In order to prove this, we examined six lakes in Rice County (Cedar, Circle, Cody, Duban, Shields, and Union (Figure 1)). Data was collected for the lakes' temperature, conductivity, salinity, and dissolved oxygen content. In all of the locations sampled, the lakes were loaded downhill from roads where road salting is frequent and the residual pesticides from neighboring farms and the road salt likely reach the water further suggesting that the impact on water quality during the winter is potentially significant. This study will help to determine changes in temperature, salinity, nutrient cycling, lower dissolved oxygen content, and degraded water quality (Stefan & Georgiou, 2001) in Rice County lakes during the winter. As a result the findings of this experiment will aid in the ongoing comparison of the lakes during the span of the year.

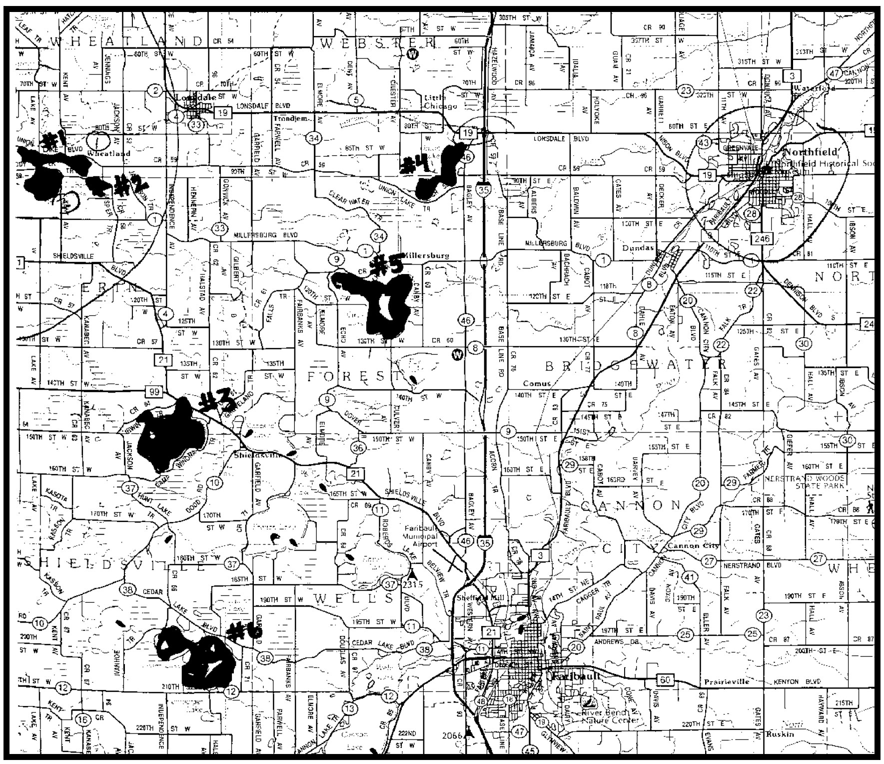

Figure 1. Locations of samples lakes in Rice County, Minnesota

Lakes Sampled:

1. Cody Lake
2. Duban Lake
3. Shields Lake
4. Union Lake
5. Circle Lake
6. Cedar Lake

Methods

The execution of our project involved two phases of methodology: our water sampling in the field and analysis in the lab. The first phase consisted of driving to nearby lakes in the county to obtain samples. We sampled six Rice County lakes, those being Cedar, Circle, Cody, Duban, Shields and Union Lake. These lakes were chosen for because previous data existed for each of them, as a result of the geology projects of former Carleton College students. At two of the locations (Union and Circle Lake), we took our samples from shallow water off the shoreline, where small patches of open water remained. At the remaining four locations (Cedar, Cody, Duban and Shields Lakes), an ice auger was utilized to drill through the frozen lake surface so as to obtain water access. At these frozen locations, drilling was done approximately 50 meters from shore (see picture above). A Yellow Springs Instrument 85 (YSI) instrument was then used to measure conductivity, temperature, dissolved oxygen content, and salinity, and we collected a small sample of water to be brought back for laboratory analysis. Our water samples were then refrigerated until the second phase of the experiment, when we carried out our analysis of both cations and using the Ion Chromatograph**.** We attempted to measure silicon amounts using an ion chromatograph, but due to silicon's very light mass, an accurate calibration curve could not be constructed.

Results

On January 30th, 2006 field samples and data from both Union Lake and Circle Lakes were collected. The temperature of Union Lake was 1.6° C, and the conductivity was 337.2 µs. Readings for the dissolved oxygen content and the salinity of the water were not obtained due to battery loss. At Circle Lake, the temperature was measured to be 2.0° C, and the salinity measured at 0.2 ppt. The conductivity of Circle Lake was 512.0 µs, and again, the dissolved oxygen reading was not able to be collected.

On February 13th, 2006 we collected samples and data from Duban, Cody, Shields and Cedar Lakes. At Duban Lake, the temperature was 0.7° C and the water had a conductivity rating of 339.6 µs. The salinity at Duban Lake was .3 ppt, and the dissolved oxygen content was 5.11 mg/L. Cody Lake was colder than Duban with a temperature of 0.4° C. The conductivity in Cody Lake was 363.9 µs, and had the same salinity as Duban at .3 ppt. The dissolved oxygen content at Cody Lake was 4.98 mg/L. Shields Lake had a temperature of 1.2° C. The conductivity was 210.5 µs, and the dissolved oxygen content was measured to be 4.14 mg/L. Shields Lake had a salinity rating of 0.2 ppt. The temperature of Cdar lake was found to be 0.9° C. The conductivity in Cedar was 156.7 µs, and the salinity rating was 0.1 ppt. The dissolved oxygen content in Cedar Lake was measured at 4.19 mg/L.

Of the water quality measurements collected in the field, salinity remained the most constant. It varied between 0.1 and 0.3 ppt with an average salinity of 0.24 ppt. We found the temperature of the water to vary between 0.4 and 2.0° C. Circle Lake had the warmest water at 2.0° C, the average temperature was 1.13° C. The results for dissolved oxygen were also fairly constant, ranging between 4.14 and 5.11 mg/L, with an average dissolved oxygen content of 4.58 mg/L. Conductivity measurements were by far the least consistent. Cedar Lake registered the lowest reading at 156.7 µs with Circle Lake on the other end of the spectrum at 512.0 µs. The average conductivity was 320.0 µs.

Lake Name	Date Visited (2006)	Temp (°C)	Salinity (ppt)	Conductivity (µs)	Dissolved Oxygen mg/L)
Cedar	2/13/06	0.9	0.1	156.7	4.19
Circle	1/30/06	2.0	0.2	512.0	No data
Cody	2/13/06	0.4	0.3	363.9	4.89
Duban	2/13/06	0.7	0.3	339.6	5.11
Shields	2/13/06	1.2	0.3	210.5	4.14
Union	1/30/06	1.6	No data	337.2	No data

Table 1. Water Quality Measurements.

Cedar Lake

Cations	
Lithium	na
Ammonium	10.6033
Sodium	1.3849
Potassium	19.8854
Magnesium	24.6476
Calcium	24.0548

Duban Lake

Cations	
Lithium	na
Ammonium	32.6111
Sodium	3.7321
Potassium	25.8122
Magnesium	48.4006
Calcium	59.2629

Circle Lake

Cations	
Lithium	0.0315
Ammonium	14.6596
Sodium	1.6014
Potassium	16.4061
Magnesium	45.4881
Calcium	53.5899

Shields Lake

Cations	
Lithium	0.0379
Ammonium	15.5578
Sodium	2.0142
Potassium	24.4535
Magnesium	58.5430
Calcium	73.7529

Cody Lake

Cations	
Lithium	0.0406
Ammonium	19.0589
Sodium	6.3105
Potassium	22.5502
Magnesium	58.5933
Calcium	76.0871

Union Lake

Cations	
Lithium	na
Ammonium	11.2557
Sodium	0.8950
Potassium	21.4792
Magnesium	30.5158
Calcium	37.8258

Table 2. Ion Analysis of lake samples.

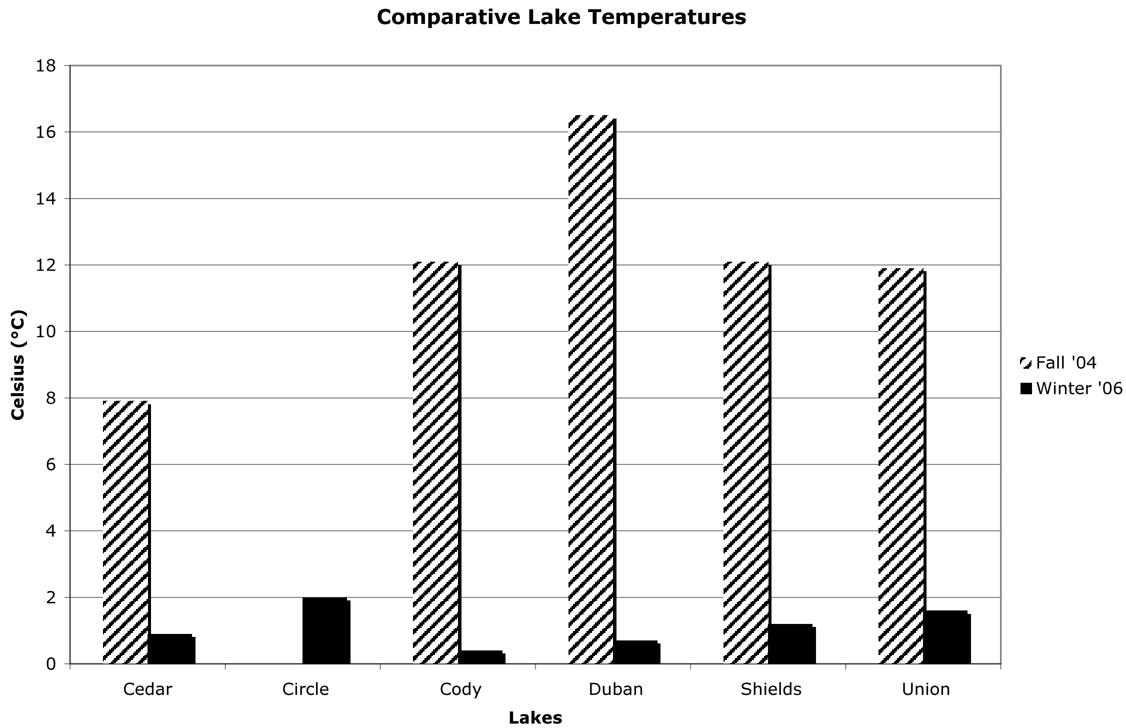

Figure 2. Temperatures from Lakes Visited in Fall and Winter.

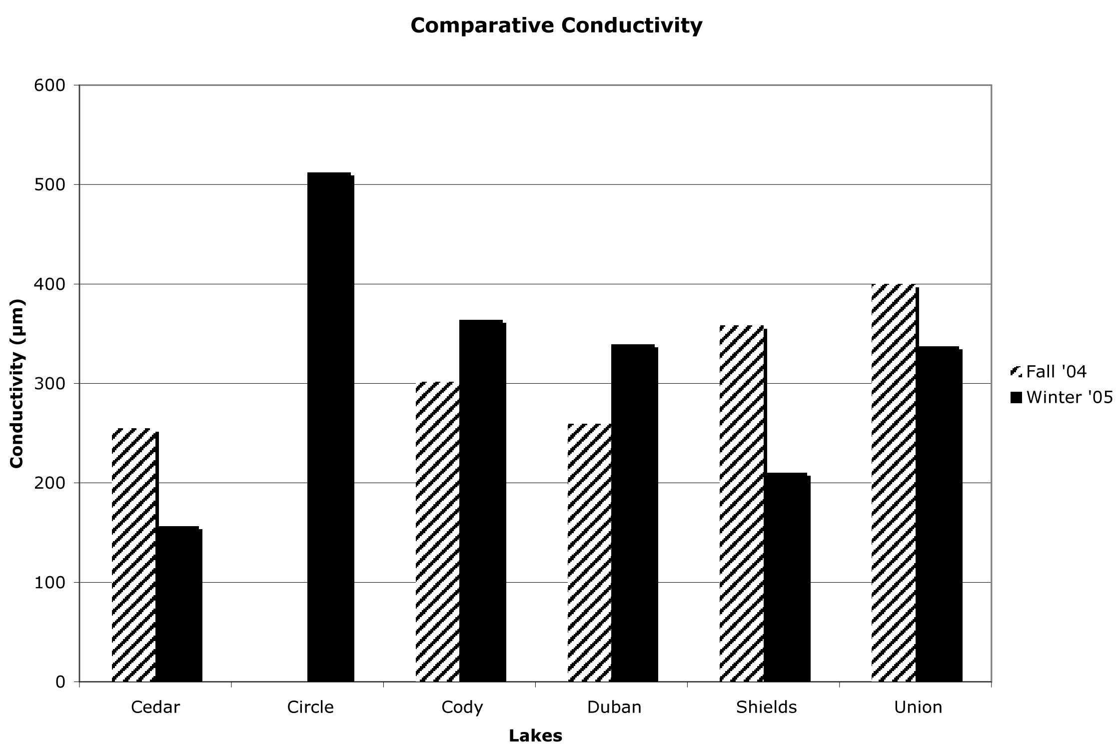

Figure 3. Conductivity from Lakes Visited in Fall and Winter.

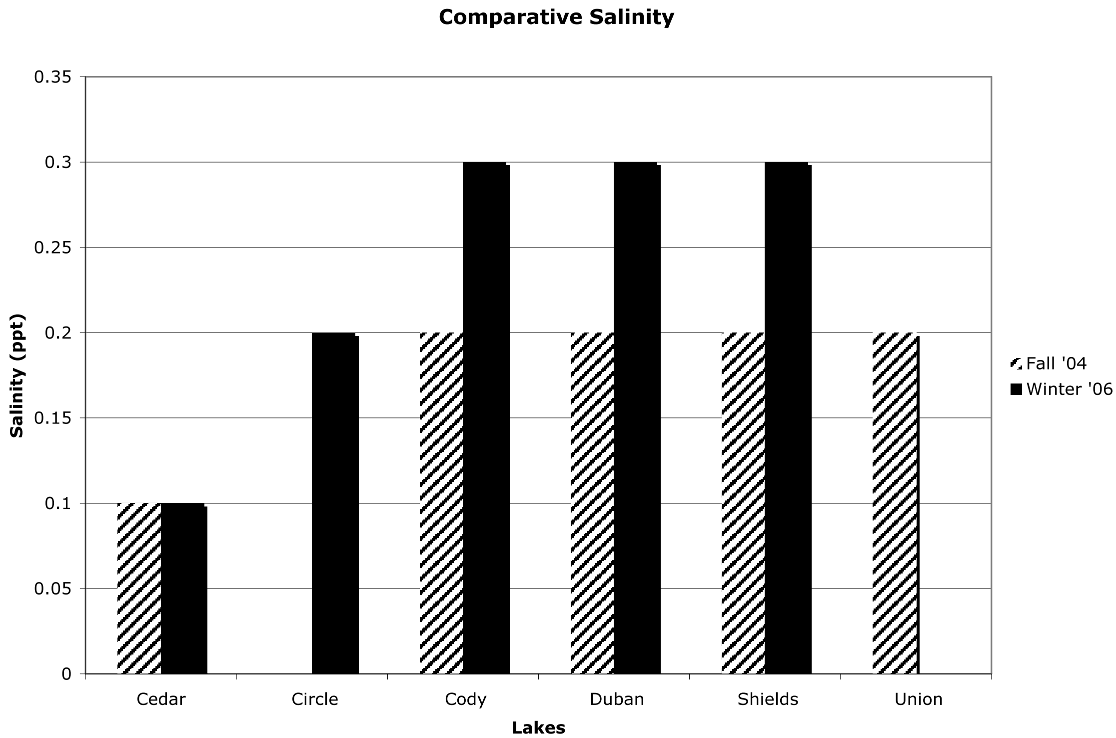

Figure 4. Salinity from Lakes Visited in Fall and Winter.

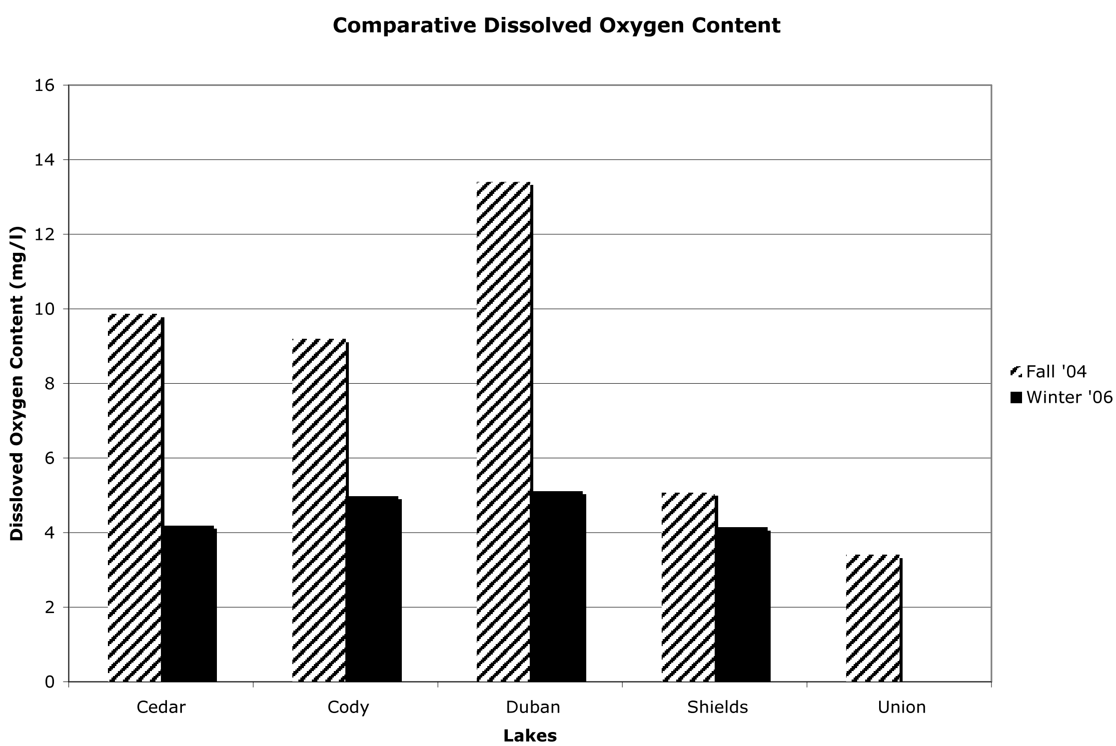

Figure 5. Dissolved Oxygen Content from Lakes Visited in Fall and Winter

Discussion

It was no big surprise that the water temperature was significantly and consistently lower than in the fall (see fig. 2). However, compared to other winters, it has been particularly warm, and further research is needed to fully understand the effects that the warming trend will have on lakes and water quality. According to the work of Stefan and Georgiou, "lakes are known to be sensitive to a wide array of changes in climate. Even small changes in climate can produce large changes in lake levels and salinity. As air temperatures increase, fewer streams in high-latitude areas will freeze to the bottom and the number of ice-free days will increase, leading to increases in the nutrient cycling and productivity" (Stefan & Georgiou, 2001).

We struggled to make conclusions about comparative values about the ion analysis results because due to system malfunction, we didn't get anion results, and there was no previous data for cations in the lakes that we studied. Therefore, we looked at the primarily the water quality measurements in analyzing our data, and although we cannot interpret our results meaningfully at this point, we hope that our data will prove useful in future studies.

We do have information on the anion content in the specific lakes from Fall 2004 studies. As predicted, our results as compared to the Fall '04 results showed that salinity is greater in the winter (see fig. 4). This can be attributed to the use of road salt application on the roads during the winter. Indeed, all of the lakes sampled were located downhill from nearby roads, making them particularly susceptible to salt runoff. In addition, the higher sodium values can be explained by road salt runoff since it is primarily comprised of sodium and chloride. As a result of global warming, southern

Minnesota is experiencing increased precipitation and therefore increases the road salt and agricultural road salt (Stefan and Georgiou, 2001).

Though we have no comparative data, high levels of calcium would be explained by the abundance of dolomite and limestone found in Southern Minnesotan bedrock. Both of these sedimentary rock types contain large quantities of calcium that can easily infiltrate both ground and surface water. Also, typical values for areas rich in magnesium-containing rock lie between 10 and 50 mg/l. Our average magnesium value was 44.4 mg/l, which falls at the high end of the given range. Like calcium, we attribute this to the dolomite rocks, which tend to be magnesium rich. High ammonium levels are often linked to animal waste, from agricultural practices, as well as from sewage and septic leaks.

Our results for the dissolved oxygen content need to be evaluated with the knowledge that the YSI meter is a sensitive machine, and for most accurate results should be calibrated everyday. With that in mind, we found that winter dissolved oxygen content of the lakes to be consistently lower than the results from the previous fall. Since cool water can hold more dissolved oxygen than warmer water (EPA, 2006) these results were initially surprising to us; however, there are many factors at play beyond the dissolved gas capacity of the water. We attribute the decreased winter oxygen trend to the fact that the lake flora is inactive during the winter, and ceases to produce oxygen through photosynthesis. In addition to the lack of oxygen production, other factors such as oxygen consumption as lake organisms continue to respire, and the frozen lake's lack of exposure to air would further contribute to the decreased oxygen levels that we found.

Conclusion

The strongest conclusion we were able to make attributed the higher salinity level in the winter as compared to the fall, to greater road salt application. However, we wonder whether, during the spring thaw, the salinity level will be even greater. From the data we collected, it is difficult to draw specific conclusions about winter lake water quality. This is because there has been little documentation of cation levels. Cations are generally not tested for because they tend to be retained by the soil, whereas anions such as nitrate, nitrite and phosphorous, leach into water systems more readily and are clear indicators of human impact. However, cations levels for sodium (connected to road salt, fertilizers and human waste) and potassium (found in potash fertilizer and animal waste) should be monitored since they too will indicate pollution and may furthermore lead to conclusions about soil cation capacity and soil health. We have discovered that there is a significant lack of research being done on winter water quality, especially cation measurement. Given that current human pressure on the land is increasing coupled with the changes in climate, it is likely that water characteristics will shift considerably, possibly endangering lake and human life. From this project we learned the importance of sufficient sample sizes. If we had collected more samples from more lakes, or if we had collected multiple samples from the original six lakes, we would have had enough data to test an internal hypothesis. Instead, we relied on comparisons with previous data, which narrowed our potential for scientific discovery. We hope that this project will serve as a stepping stone in providing helpful data and inspiration for future winter studies on lake water.

Acknowledgements

We would especially like to thank Bereket Haileab for his continuous support and tireless babysitting of the erratic conductivity meter. We would also like to thank our TAs Nick Riordan and Kelsey Dyck for providing transportation, help with the collection of samples, interpretation of results, and general geologic cunning. We would like to further extend our gratitude to the Carleton College Geology Department for providing the equipment, materials, and space necessary to execute this project. Finally, we owe thanks to the Fox Lake resident who roused himself from bed to rescue our van from the ditch.

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