An Investigation into the Water Quality of Lyman Lakes and Spring Creek

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Introduction

Agriculture, an important part of the southern Minnesotan economy and lifestyle, can have wide-reaching ecological effects beyond the cropland. Runoff from agricultural and commercial property often easily infiltrates nearby water sources, affecting their chemical makeup and, in turn, affecting nearby ecosystems. Nitrogen is one of the main contaminants which results from this runoff. Some harmful effects of nitrogen on watersheds include acidification of soil and surface water, demise of seagrass beds, increase in algal blooms, loss of biodiversity, and oxygen depletion resulting in the killing of fish (Driscoll, C.T., et al. 2003). Furthermore, the flux of nitrate and other elements into southern Minnesotan streams has increased in recent years, as evidenced by the fact that the nitrate levels in the Mississippi River have tripled since 1970 (Goolsby, et al, 2000). One of the many tributaries which contributes to the makeup of the Mississippi River is Spring Creek in southeastern Minnesota. This study will focus on the length of Spring Creek that includes Lyman Lakes on the Carleton College campus in Northfield, MN, as well as a length that runs upstream from campus toward the Northfield Golf Course. (fig 1)

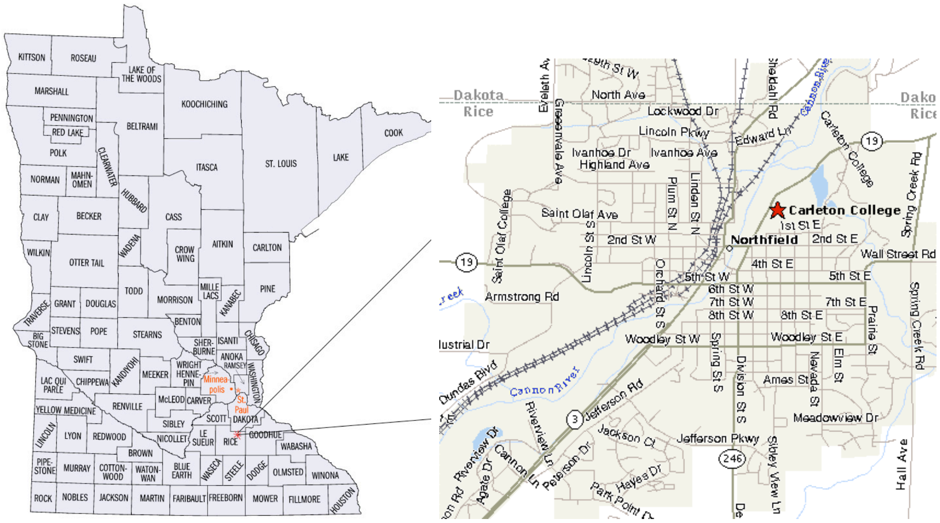

Figure 1: Location of Spring Creek and Lyman Lakes in Minnesota

Previous studies on Spring Creek and Lyman Lakes have identified nitrogen as the most abundant pollutant. We expect that this comes mostly from the nearby golf course through which Spring Creek runs. Lyman Lakes are on the property of Carleton College, which has used cornmeal fertilizer exclusively since 2003 (personal correspondence with Dennis Easley). Therefore, we expect that Carleton's contribution to the nitrogen content of the water is minimal. However, to our knowledge, no study has ever been done on the water quality in the winter, when fields and the golf course are fertilized much less frequently, if ever. We hoped to identify the nitrogen from its source, which, we hypothesized, could be the Northfield golf course.

To identify where the nitrogen was coming from, we collected 26 water samples from a greater section of Spring Creek and Lyman Lakes than was previously tested. (fig 2, 3) We expect to find that the nitrogen in the lakes come mostly from Bell Field and the Northfield Golf Club. By being the first group to test in the winter, we will further the understanding about the source of these cations and anions, because fertilizer will be applied much less frequently, if at all, and frozen ground may mean less runoff into the Spring Creek system. After completing numerous tests for cations and anions in the water samples, we hope to come closer to pinpointing the source of these impurities and make recommendations on what Carleton College and the city of Northfield can do to improve water quality.

Previous Work

In 2000, Carleton College senior Annie Winkler compiled the previous studies on Spring Creek into a comprehensive report on the health and future of the watershed. Winkler declared that the agricultural activity and recent development and rerouting of Spring Creek upstream from the Carleton campus made frequent monitoring of the stream a necessity. Additional research, focusing solely on the Upper Lyman Lake portion of the Spring Creek system, was initiated by a group of Carleton students in the spring of 2003. Both of these studies found that the nitrogen levels in Upper Lyman Lakes were causing the lake to be highly eutrophic.

The most recent study of the stream system, completed in the fall of 2004 by Carleton students, found that nitrogen levels were the closest of any anion to exceeding the EPA's suggested amount for safe drinking water. They found that this nitrogen content was highest—up to 24 mg/L—in Upper Spring Creek and Upper Lyman Lake, a fact that led them to hypothesize that these high levels were the result of ammonia-rich fertilizer from the Northfield Golf Course and from upstream agriculture. In beginning our study, we hoped to build on these past studies on the impurity levels of Spring Creek and test this most recent hypothesis by taking samples from sites that were more remote from Lyman Lakes than those that had been tested previously.

Methods

To analyze both the lakes and their sources, we used a Model 85 Yellow Springs Instrument to measure the conductivity, salinity, and temperature at each site. We also used a Dionex 600 Ion Chromatographer, which sent a small amount of each sample through a tube of ion exchangers, serparating the anions and cations by affinity. The cations are changed into their acidic forms, and then measured by a specific conductance detector, which determines the type and amount of each cation by comparing it to a standard (fig 2). This method allowed us to test each water sample for the magnesium and calcium cations. For the potassium, sodium, and ammonium cations, we compared the peak levels from the Dionex Chromatographer to the calibration curve created by an earlier group to discern an approximate amount of each element. Unfortunately, the Ion Chromatographer malfunctioned before we were able to test our samples for the fluoride, chloride, nitrate, nitrite and sulfate anions, limiting the scope of our conclusions.

However, we were able to calculate some nitrogen levels using the amount of ammonium ions, since they are made up of one atom of nitrogen. This does not account for all of the nitrogen because the other two main carriers of nitrogen, nitrates and nitrites, were not accounted for, but it gives us an idea of how the levels now compare to those in the fall.

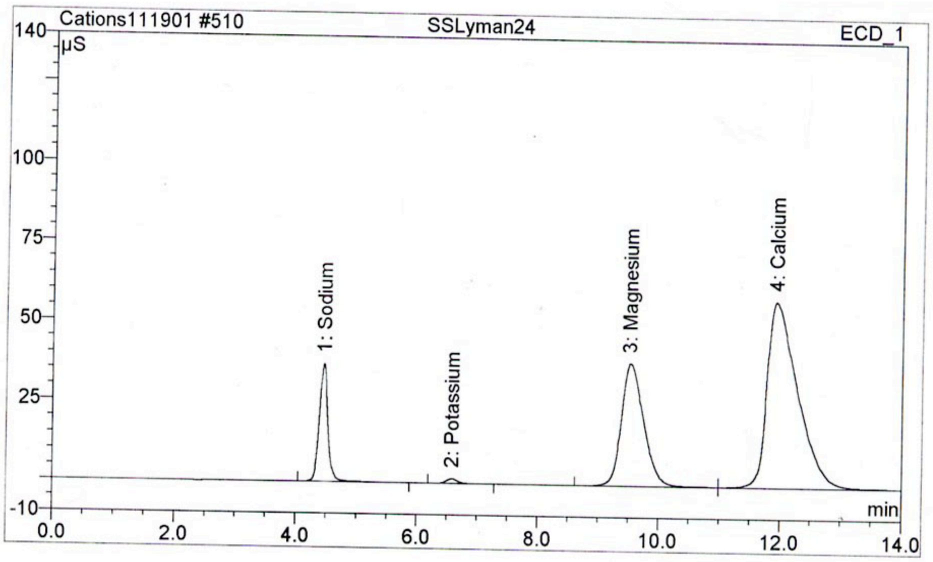

Figure 2: Sample Cation Printout from Dionex 600 Ion Chromatographer

Our samples were taken on some of the coldest winter days in January and February, in a span of three weeks between January 31 and February 21. We have taken 15 samples from along the length of Spring Creek. These samples of Spring Creek were taken about 100 meters apart between Lyman Lakes and the pond at the Northfield golf course (fig 4). In our experiment, knowing the elements present in Spring Creek all the way downstream to Lyman Lakes is as important as knowing the chemicals present in the lakes themselves. We have also taken six samples from the upper Lyman Lake and five from Lower Lyman (fig 3). The samples are ordered from upstream (at the golf course) to downstream (Lower Lyman) throughout our analysis, to make trends in water quality more apparent.

Because past experiments on the Spring Creek system were conducted in the fall and in the spring, we feel that our winter results might be slightly different, possibly illuminating the source of the high nitrogen levels. For example, there should be less animal waste polluting the waters and less nitrogen because agricultural fertilizer is seldom used during Minnesota winter.

Figure 3: Upstream Sample Locations Upstream

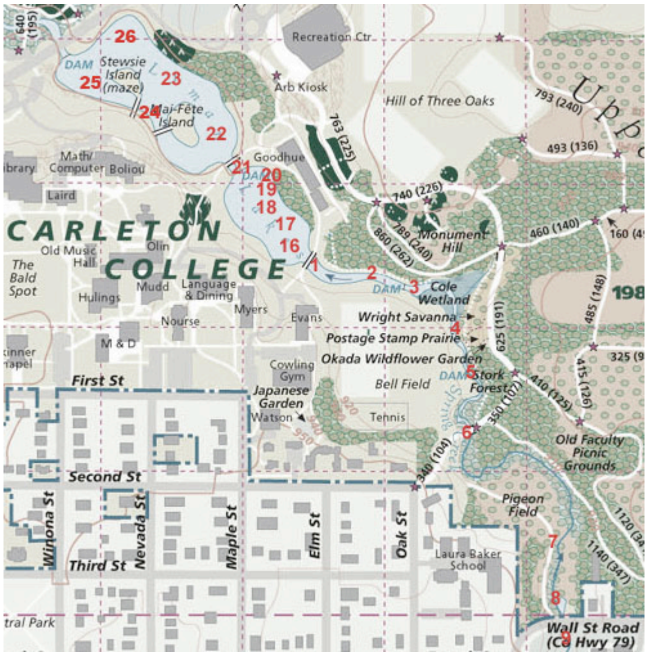

Figure 4: Sample Locations on Carleton Campus

Results

Table 1: Complete Test Results for each Site

Site Numbers organized by site location: upstream to downstream

Site #	Temp (°C)	Conductivity (µs)	Spec.Cond. (µs)	Salinity (ppt)	Mg (ppt)	Ca (ppt)	Na (ppt)	K (ppt)	NH4 (ppt)
15	N/A	N/A	N/A	N/A	42.26	129.50	31.944	11.135	0

Site #	Temp (°C)	Conductivity (µs)	Spec.Cond. (µs)	Salinity (ppt)	Mg (ppt)	Ca (ppt)	Na (ppt)	K (ppt)	NH4 (ppt)
14	3.2	387.8	662	.3	37.95	115.37	31.609	6.267	0
13	2.3	418.4	735	.4	37.34	115.57	34.015	10.559	0
12	2.3	416.2	734	.4	18.08	46.98	16.350	3.484	0.0
11	3.2	347.5	597	.3	38.88	122.84	37.779	9.943	.544
10	3.6	437.8	739	.4	39.74	125.27	35.272	7.721	0
9	3.5	415.5	704	.3	40.50	124.33	34.538	8.267	0
8	3.5	359.7	609	.3	36.26	115.88	46.638	9.444	0
7	4.1	416	695	.3	N/A	N/A	N/A	N/A	N/A
6	4.2	422.6	701	.3	35.65	111.81	49.833	9.347	0
5	4.3	423.7	700	.3	39.72	122.97	34.142	8.610	0
4	4.6	426.7	699	.3	38.71	118.68	37.92	8.802	0
3	4.6	432	708	.3	38.69	105.36	40.229	8.913	.612
2	4.9	N/A	707	.3	41.15	118.60	34.613	8.535	0
1	4.2	428.6	705	.3	43.23	124.78	31.439	8.590	0
16	3.4	445	751	.4	37.06	113.71	26.099	6.413	0
17	1.0	368.7	771	.3	41.50	127.23	28.736	7.141	0
18	2.2	337	781	.3	36.23	111.54	25.531	7.191	.444
19	2.7	411	774	.3	27.11	82.61	18.622	5.156	.398
20	2.7	444	773	.4	42.08	129.66	31.965	7.302	0
21	2.5	440	773	.4	36.85	113.93	29.255	7.646	1.063
22	0.1	384	770	.3	38.62	118.95	30.425	7.509	.654
23	0.1	449.2	771	.4	43.25	133.80	34.395	9.161	0

24	2.8	291.3	501	.2	43.30	133.67	36.672	7.853	0
Site #	**Temp (°C)**	**Conductivity (µs)**	**Spec.Cond. (µs)**	**Salinity (ppt)**	**Mg (ppt)**	**Ca (ppt)**	**Na (ppt)**	**K (ppt)**	**NH4 (ppt)**
25	.1	439.2	N/A	.4	44.21	138.29	34.113	7.757	0
26	.4	432.4	N/A	.4	N/A	N/A	N/A	N/A	0

N/A= Measurement not able to be taken.

Table 2: Descriptive Statistics

	Minimum	Maximum	Mean
Temperature	0.1	4.9	2.82
Conductivity	291.3	449.2	407.26
Salinity	0.2	0.4	0.332
Magnesium	18.08	44.21	38.27
Calcium	46.98	138.29	116.72
Potassium	3.48	11.14	8.03
Amonium	0	1.06	0.1498

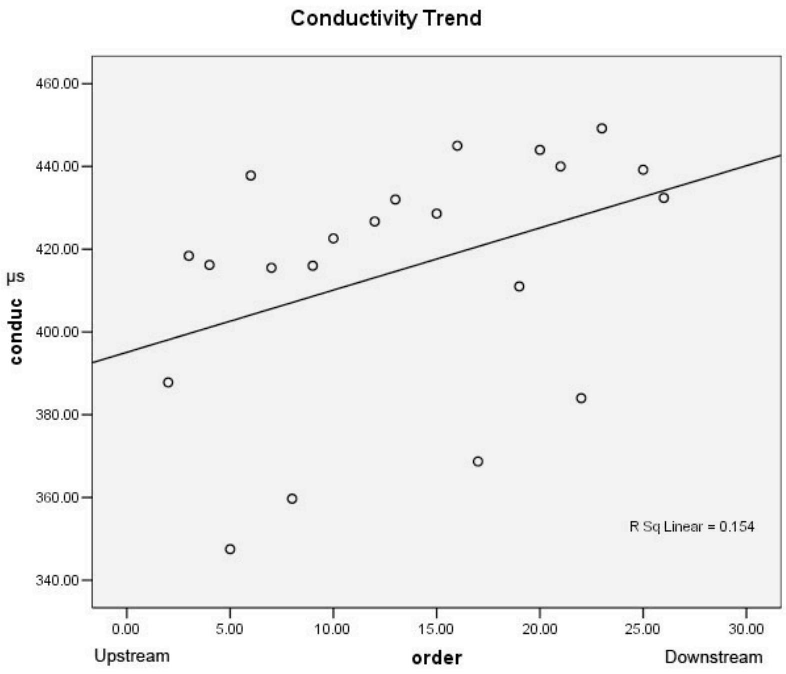

Figure 5: Conductivity trends, upstream to downstream

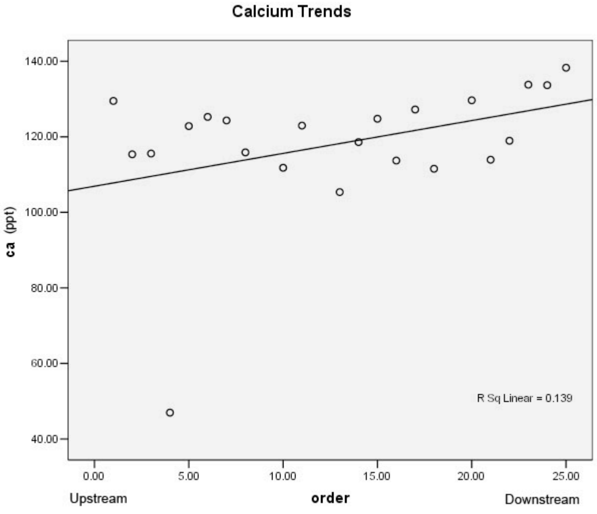

Figure 6: Calcium trends, upstream to downstream

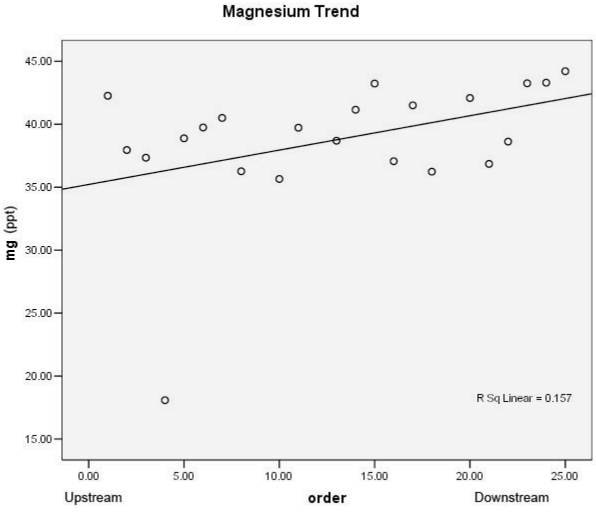

Figure 7: Magnesium trends, upstream to downstream

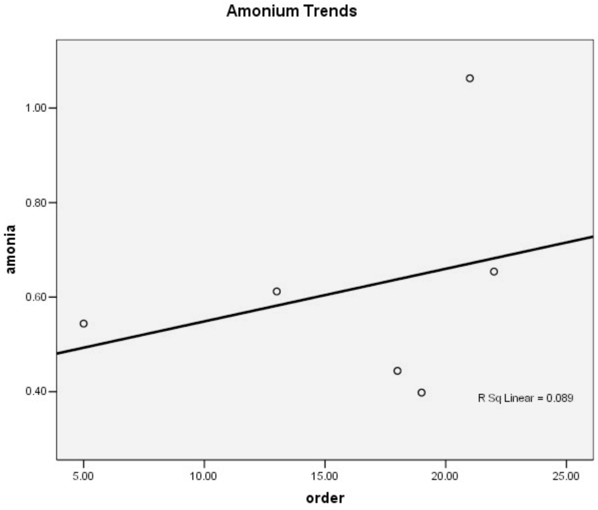

Figure 8: Amonium trends, upstream to downstream

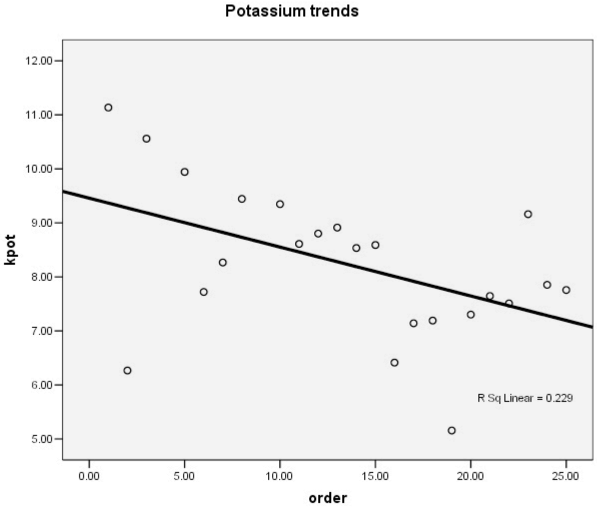

Figure 9: Potassium trends, upstream to downstream

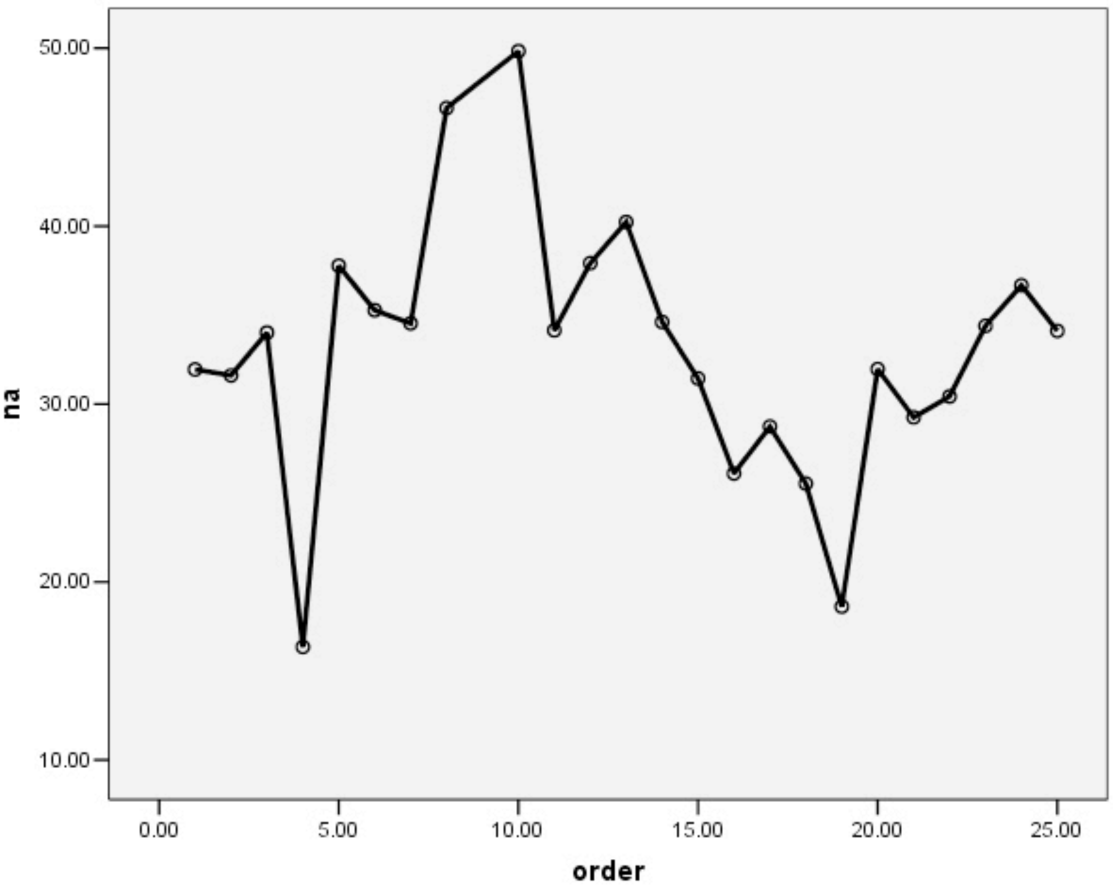

Figure 10: Sodium trends in ppt, upstream to downstream.

Discussion

After collecting and compiling the data for each sample site and ordering it from upstream to downstream (Table 1), we began to look for discernable trends. The temperatures that we recorded at each site varied greatly and showed no general trend, undoubtedly due to the various depths at which we took the samples and the amounts of ice cover present at the different sample sites. The salinity levels, as measured in the field with a Yellow Springs Instrument, stayed fairly constant at .3 or .4 ppt at every test site, providing no valuable insights into the quality of the body of water.

A trend did present itself as we began to analyze conductivity levels. We saw a slight overall rise in conductivity from the samples taken upstream to the samples taken downstream (Figure 5). Sample 14, taken from the furthest site upstream, had a conductivity reading of 387.8 µs, while sample 26, from the furthest site downstream, had a conductivity reading of 432.4 µs: an increase of over 40 µs. There was also a small rise in amount of several cations, such as calcium (Figure 6) and Magnesium (Figure 7). This parallel rise in conductivity and cations can be explained based on the general correlation between the amount of total dissolved solids in a sample and the sample's conductivity.

Even though we were not able to test our samples for anions, the rise in conductivity, a function of the cations and anions present in a sample, suggests that there could be more anions present in Spring Creek as it flows downstream. This is also supported by the data on anions gathered in 2004 by Carleton College students, who found that the average amount of anions present increased between Upper Spring Creek and Upper Lyman Lake.

Next, we looked for trends present for each of the individual cations. A comparison between Ammonium (fig 8) and Potassium (fig 9) levels illuminates the ability of the stream bed to absorb these elements. Ammonium is one of the three main nitrogen ions that are found in the water, the other two being nitrates (NO_3^-) and nitrites (NO_2^-). The trend of ammonium increasing downstream correlates directly with the trend of potassium decreasing downstream. Some of the potassium is undoubtedly absorbed by the water, but some of it also blocks the ability for the nitrogenous ammonia to stabilize itself in the soil or clay bottom. As the positively-charged ammonium ion moves downstream, it is attracted to the negatively-charged surfaces of clay and organic substances on the bottom. However, potassium reacts the same way to the negatively-charged organic substances, so if there is potassium in the water, it reduces the surfaces available for the nitrogen to bond. So as the amount of potassium in the water decreases because it is attaching to the floor, it is displacing the ammonium, increasing the amount of ammonium ions in the water (Seelig and Nowatzi 2000). The increased amount of ammonium downstream could also be attributed to a higher level of waterfowl activity on Lyman Lakes, because ammonium can also be the result of duck or geese excretions.

The pattern observed in sodium (figure 10) is especially noteworthy. At site numbers 8 and 10 on the graph, we see a spike in sodium levels from previous levels of 34.538 ppt to 46.638 and 49.833 ppt., respectively. These samples were taken from a location in which Spring Creek runs underneath the Wall Street Bridge. Wall Street is a paved road which is de-iced with road salt during the winter months, and the subsequent runoff of this road salt directly into Spring Creek clearly has a great effect on the sodium levels in the creek. As the samples move further downstream from Wall Street, less sodium is present, a result of the creek's natural filtration processes. By the time the water reaches Upper Lyman Lake, the sodium levels have returned to around 31 ppm. Another small spike in sodium levels also occurs at point 20 on the graph, which corresponds with the sample site underneath the Goodhue footbridge. Therefore, it can be said that the winter salt runoff from these bridges has a great affect on the sodium levels in Lyman Lakes and Spring Creek.

Conclusions

Unfortunately, due to technological difficulties, we were not actually able to obtain a complete set of results. As a guideline for future study, we suggest that groups allow plenty of time in case a machine malfunctions. However, we were still able to measure cations and draw several conclusions from this data.

We clearly saw the dramatic effects of road salt runoff on the sodium levels of Spring Creek. This spike in sodium may be cause for futher study, as higher than normal sodium levels can affect macroorganisms, in turn disrupting the entire aquatic ecosystem (Environmental 2006). Alternatives to sodium chloride, unfortunately, are too expensive to be viable for many towns such as Northfield, as they cost almost twenty times the amount of common road salt (Environmental 2006).

Since Carleton College has used entirely cornmeal fertilizer since 2003, we know that the fertilizer runoff from the Carleton campus is not affecting the nitrogen content. However, our communication with the Northfield Golf Course indicates that their fertilizers, which are usually applied during spring through fall, are nitrogen-based. Therefore, we inferred that the relatively high nitrogen levels found in 2004 resulted from runoff from the golf course. However, since we conducted our study in winter, we found hardly any nitrogen present. This is to be expected, as the golf course is not fertilized during the winter months and runoff is limited because the ground is frozen. Interestingly, the small nitrogen amounts we found decreased downstream, whereas the fall 2004 study showed nitrogen increasing downstream. We concluded that since little additional nitrogen is entering the water, the soil surrounding the water adsorbed much of the nitrogen left over from warmer months (Seelig and Nowatzki 2001). However, it is important to remember that we do not have full statistics on nitrogen; nitrates are the main source of nitrogen, and we only have the amounts from the ammonium ions. Also, studies conducted during the spring and summer months on the effects of nitrogen runoff from the golf course and Bell Field would perhaps help elucidate long-term effects on water quality in Spring Creek and Lyman Lakes.

Acknowledgements

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