Paul Smith's College

Adirondack Watershed Institute

Technical Report | Limnology and Water Quality Program

Blue Mountain Lake Watershed Monitoring Program

Project Update: 2016

Paul Smith's College
Adirondack Watershed Institute

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Report Summary

The Blue Mountain Lake watershed has been monitored by the Adirondack Watershed Institute in one form or another for the past 24 years. In 2015, the program was changed from one that performed nutrient analysis on specific segments of two tributaries (Museum and Potter Brooks); to one that takes a more comprehensive look at the five major streams flowing into the lake. The goal of this enhanced program is to gain a better understanding of nutrient loading to the lake and the impact of road deicers. To support the upgraded program, each stream was instrumented with stage recorders and in-stream conductivity meters. This report serves as an overview of the first two years of monitoring.

1. The level loggers and conductivity meters installed in the streams are all performing as expected. The data has been downloaded on a regular basis since October of 2015.

2. Correlation between the stream height recorded by the Levelogger and discharge for the study streams is very good, with coefficient of determination values (R^2) exceeding 0.87. Full development of the stage-discharge curves and conductivity-chloride relationships will take at least one more field season. Once the relationships are developed we will be able to determine stream discharge and the amount of road salt contaminants entering the lake at 30 minute intervals for the sub-watersheds.

3. The stream water entering Blue Mountain Lake is acidic in the early spring, and circumneutral the remainder of the field season. The streams tended to have moderate acid neutralizing ability.

4. The greatest export of phosphorus and nitrate comes from Museum Brook. The elevated concentrations are likely related to the permitted discharge from the Adirondack Museum. Overall, nutrient export to the lake is quite low from all of the tributaries (including Museum Brook) and is within the range of nutrient export observed for other unimpacted streams in the Adirondacks.

5. The eastern side of the Blue Mountain Lake watershed is significantly influenced by road salt. In general, export of sodium and chloride to the lake increases with road density in the sub watersheds.

6. Beaver Brook is the only sub-watershed that lacks salted roads. Our initial calculations estimate that Beaver Brook exports 0.3 kg of chloride per day to the lake. Sub-watersheds that contain salted roads export 70 to 200 times more chloride than Beaver Brook. For example, we estimate that on average Museum Brook exports 51 kg of chloride per day to the lake, which is more than all of the other streams combined.

7. Our loading estimates for road salt are fairly coarse because they only take into consideration a total of 11 sampling days. Data from the instream conductivity meters demonstrated that the salt loading is much higher during the spring melting period. The impacted streams also had high levels of salt during the low flow period of the summer, which indicates indicating ground water contamination. Full development of the stage discharge curves and the conductivity-chloride relationship will allow us to develop a high resolution model of salt loading to Blue Mountain Lake.

Introduction

Water Watch and the Adirondack Watershed Institute have been monitoring the Blue Mountain Lake watershed since 1993 in a semi-ongoing study referred to colloquially as the Brooks Study (Martin 1994). Historically, the monitoring has focused primarily on the analysis of nutrient concentration in specific segments of Museum and Potter Brooks in an attempt to isolate the influence of current and proposed development in those watersheds. In 2015, the approach changed from segment analysis on select streams to a more comprehensive study that included all of the major tributaries to the lake. The goal of this retooled monitoring program is to develop a more complete understanding of nutrient inputs into the lake and the impacts of road salting. Road salt, although previously not monitored, has become a pollutant of concern in Blue Mountain Lake. Recent analysis has demonstrated that chloride concentration in Blue Mountain Lake is 83 times greater than background levels (Kelting et. al 2012; Laxson et. al 2017). To bolster the new monitoring effort, stage recorders and instream conductivity meters were installed at the pour point of the five major sub watersheds and supported by regular water quality analysis. The objective of this report is to provide an update on the status of this new monitoring program.

Methods

Lake and Watershed Characteristics

Blue Mountain Lake is located within the Town of Indian Lake in the central Adirondacks (Figure 1). The lake is 697 ha in surface area and has 44 km of shoreline. The maximum depth is 30.5 m, total volume is 75,725,176 m^3, and the lake flushes approximately every 3.3 years. The watershed of the lake is 2,972 ha, 22% of this area is surface water. The watershed is dominated by forest cover, with 62% deciduous, 7% evergreen, and 7% mixed forest. There are 13 km of roads that pass through the watershed, 4km are local roads (county, town, local) and 9 km are state highway (Laxson et al. 2017).

The Blue Mountain watershed is drained by five major tributaries (Table 1). The drainage area for Minnow Pond represents the largest sub-watershed and contains a state road density of 0.70 km/km^2. Minnow Pond has two outlets at East and West Minnow Brooks, although the pond appears to drain primarily through the East Brook. Collectively the Minnow Pond and Minnow Brook watersheds drain 737 ha of land (25% of total watershed area). The second largest sub-watershed is Beaver Brook, an unimpacted catchment on the western end of the lake that lacks salted roads. Museum and Potter Brooks are the smallest sub-watersheds, containing a road density of 0.56 and 0.55 km/km^2 respectively. Fifteen percent of the Blue Mountain Lake watershed is not drained by a tributary, which constitutes the shoreline and adjacent uplands that are uncolored in Figure 1.

Field Sampling and Laboratory Analysis

Permanent monitoring stations were installed at the pour point (near the lake) of each of the five major tributaries on December 10th, 2014 (Photo 1). Each station was equipped with a submersible conductivity logger (Onset, HOBO U-24), and differential pressure transducer to measure stream height. (Solinist, Levelogger Edge). Both the Levelogger and the conductivity meter collect data at 30 minute intervals. Due to equipment backorder, the Levelogger did not begin collecting stream height data until May 6th, 2015. Study streams were visited five separate times per year, roughly one month apart between May and October, with the exception of 2016 when an additional April visit was made. During each visit a stream discharge[1] measurement was made and a water sample was collected for chemical analysis.

[1] Total volume of water leaving the stream per unit of time (typically m^3/sec).

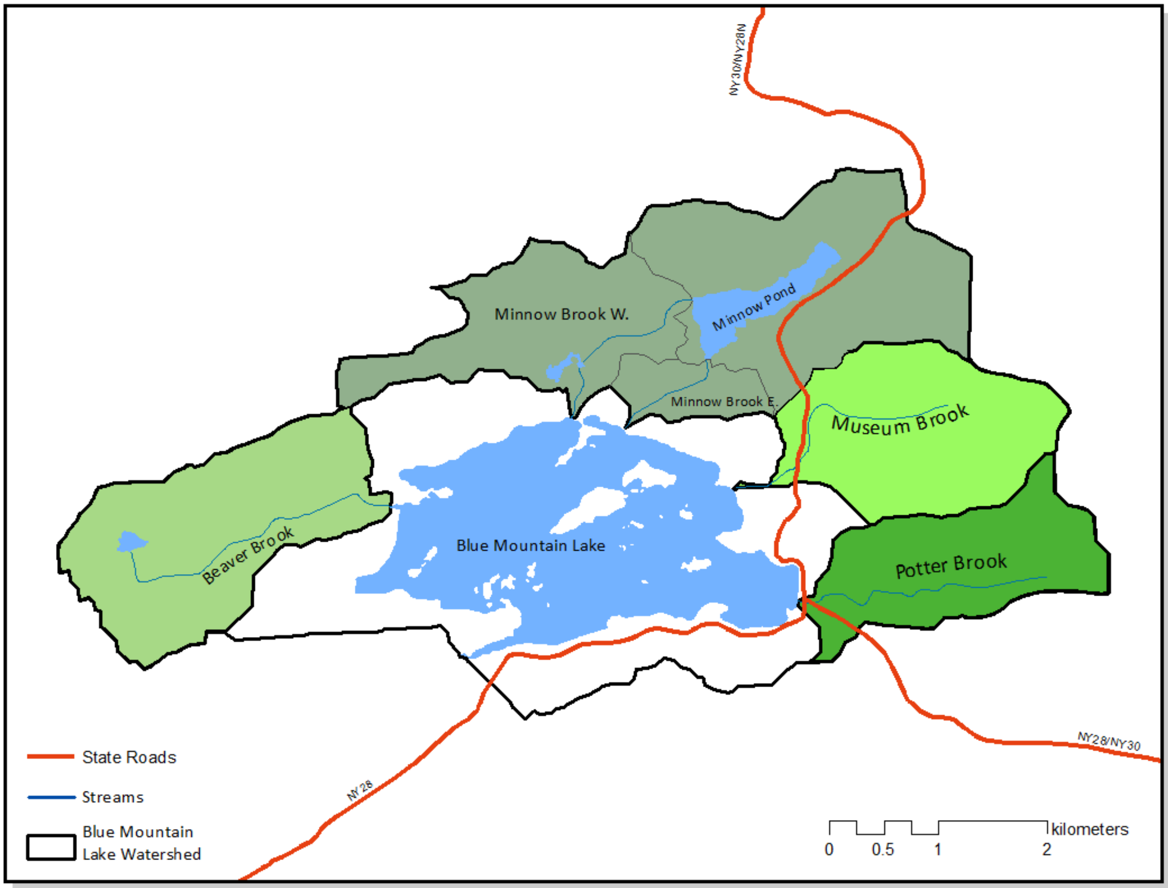

Figure 1. Sub-watersheds and major roadways of the Blue Mountain Lake catchment.

Table 1. Size and road density of each of the Blue Mountain Lake sub-watersheds.

Tributary	Watershed Area (ha)	Percent of BML Watershed	Road Density (lane km/km^2)
Minnow Ponds and Brooks	737	25	0.70
• *Minnow Pond*	411	14	0.70
• *East Minnow Brook*	66	2	0.0
• *West Minnow Brook*	260	9	0.0
Beaver Brook	374	13	0.0
Museum Brook	321	11	0.56
Potter Brook	256	9	0.55

Stream discharge was measured using standard procedures developed by the US Geological Survey (Turnipseed and Sauer 2010). Cross sectional area and stream velocity were measured at ten segments across the width of each stream using an acoustic Doppler velocity meter (SonTek, Flow Tracker ADV), these measurements were then integrated into total stream discharge (m^3/second). Rating curves for each of the study streams was developed by plotting the stream discharge against the corresponding stream height recorded by the Levelogger. Once the relationship between height and discharge is established, stream discharge can be calculated at 30 minute intervals.

Water samples were collected, preserved, and analyzed using standard methodologies. Samples were analyzed at the Adirondack Watershed Institute's Environmental Research Lab for total phosphorus (APHA 4500-P,H), nitrate+nitrite (APHA 4500 I), chloride (EPA 300.0), sodium (EPA 200.7), alkalinity (EPA 301.2), conductivity (APHA 2510-B) and pH (EPA 9040C). All laboratory analyses included quality control (QC) measures such as check standards, blanks, matrix spikes, and duplicates that were assessed on an on-going basis.

Loading Calculation

Loading is the amount of a substance (chemical, nutrient, or soil) that is lost from the watershed and imported to the lake expressed as weight/time (typically weight/day). Loading for each of the study streams was calculated by converting the instantaneous discharge (m^3/sec) to daily discharge (m^3/day), multiplied by that day's analyte concentration (mg/L). For analytes that were below laboratory detection, a zero was entered into the calculation. Areal loading (g/ha/day) was calculated by dividing the daily loading by the surface area of the sub-watersheds. Areal loading provides a better comparison of chemical flux between watersheds because the factor of watershed size is normalized. Differences in watershed loading between study sites was statistically analyzed using the Kruskal-Wallis one-way analysis of variance, a non-parametric method for testing whether samples originate from the same distribution.

Photo 1. Stream monitoring station at Minnow Brook West (left). AWI Technician measuring stream discharge at Museum Brook (right).

Results

Stream Discharge

Correlation between the stream height recorded by the Levelogger and discharge for the study streams was very good, with coefficient of determination values (R^2) exceeding 0.87 (range 0.87-0.96: Figure 2). The stage recorder at Museum brook appears to have shifted, resulting in a clear distinction between the 2015 and 2016 datasets. The rating curves are still in development and will need several additional measurements before they can be used to estimate discharge at 30 minute intervals, particularly at moderate to high discharge events. Overall, areal weighted discharge observed during the sampling days was similar between study watersheds, and averaged between 10 and 16 m^3/ha.

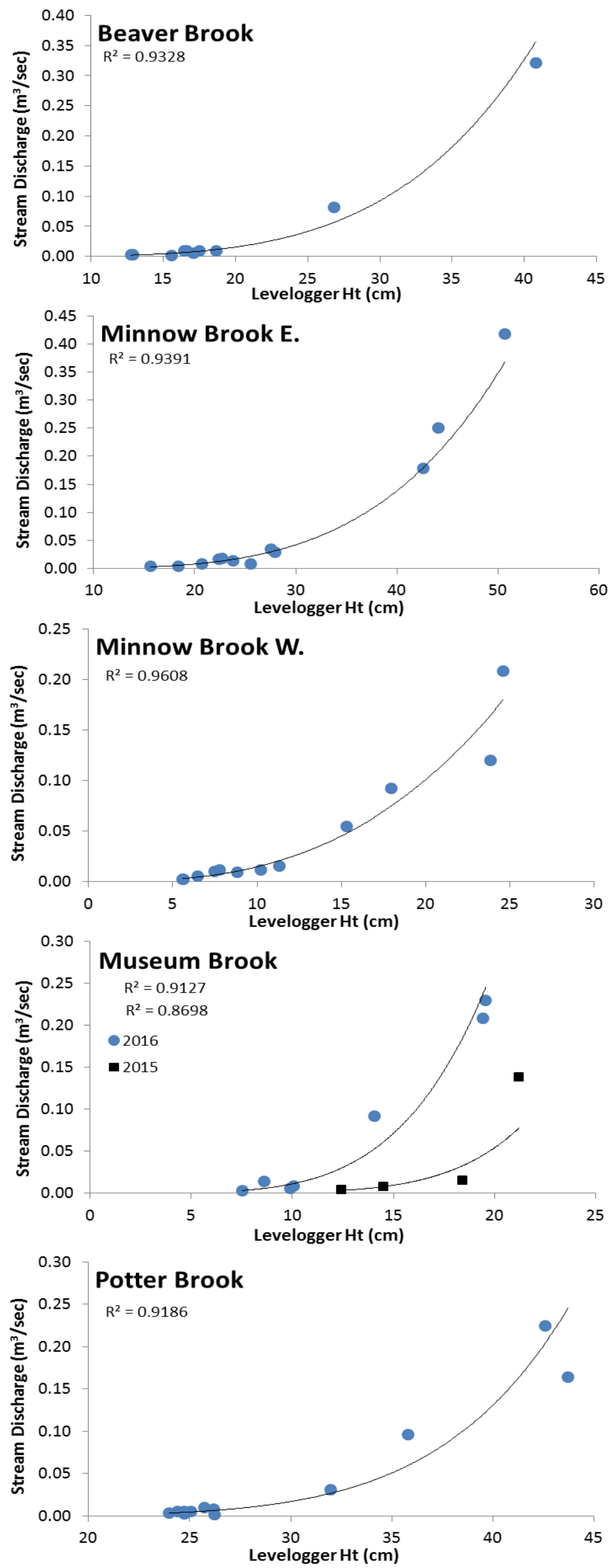

Figure 2. Rating curves of the study streams of Blue Mountain Lake.

Acidity

The study streams ranged from acidic to circumneutral depending on the time of year. In April of 2016 acidity ranged from a low of 5.1 pH units at Minnow West and Potter Brooks to a high of 5.8 at Beaver and Minnow East. The pH of the streams increased considerably during the summer months (less acidic) with typical pH values at or near 7 pH units. Alkalinity (acid neutralizing ability) was greatest in Museum Brook (average = 16.4 mg/L), followed by Potter Brook (16.1 mg/L). The lowest alkalinity was observed at Minnow Brook East (average = 6.9 mg/L: Table 2).

Total Phosphorus

Total phosphorus concentrations ranged from a low of 3 µg/L in Potter Brook on October 11th, to as high as 400 µg/L in Museum Brook on the same date. The greatest average concentration of total phosphorus was found in Museum brook, which averaged 115 µg/L during the 2016 study period. The second highest average concentration was found in Beaver Brook (17 µg/L), followed by Minnow Brook West (13 µg/L), Minnow Brook East (11 µg/L), and Potter Brook (8 µg/L: Table 2).

Table 2. Daily discharge and water quality values for the Blue Mountain Lake study streams during the 2016 sampling season.

Stream	Parameter	04/18/17	06/06/17	07/05/17	08/01/17	09/01/17	10/11/17	Average
Beaver Brook	Daily discharge m^3/day	27769	7068	242	812	838	173	6150
	Total Phosphorus (µg/L)	7.6	14.7	35.1	23.7	14.9	8.4	17.4
	Nitrate/Nitrite-N (µg/L)	173.9	110.2	112.6	185.4	57.4	169.1	134.4
	Chloride (mg/L)	0.4	0.3	0.1	0.4	0.5	0.6	0.4
	Sodium (mg/L)	0.5	0.7	1.2	1.2	1.0	1.3	1.0
	Alkalinity (mg/L)	2.9	6.0	13.7	15.6	12.7	19.1	11.7
	pH	5.8	6.4	7.1	7.1	7.0	7.0	6.7
	Specific Conductance	10.4	17.9	29.1	30.1	26.2	36.9	25.1
Minnow Brook E.	Daily discharge m^3/day	21600	1244	389	1469	1607	700	4501
	Total Phosphorus (µg/L)	15.3	6.9	8.7	6.7	24.0	4.4	11.0
	Nitrate/Nitrite-N (µg/L)	170.0	201.0	111.0	115.0	62.9	14.9	112.5
	Chloride (mg/L)	21.2	21.0	27.5	25.2	30.5	31.6	26.2
	Sodium (mg/L)	12.0	12.3	17.5	16.9	16.9	18.9	15.7
	Alkalinity (mg/L)	4.6	5.9	7.3	7.7	8.1	7.9	6.9
	pH	5.8	6.0	7.1	7.1	6.3	6.9	6.5
	Specific Conductance	80.3	84.3	106.4	95.6	103.0	110.8	96.7
Minnow Brook W.	Daily discharge m^3/day	17997	4726	458	864	968	173	4198
	Total Phosphorus (µg/L)	12.3	21.4	13.8	12.2	13.8	7.6	13.5
	Nitrate/Nitrite-N (µg/L)	249.0	51.4	42.0	160.0	36.5	245.0	130.7
	Chloride (mg/L)	0.4	0.2	0.2	0.6	0.3	0.5	0.4
	Sodium (mg/L)	0.5	0.7	1.1	1.1	0.9	1.2	0.9
	Alkalinity (mg/L)	5.3	9.7	11.6	14.1	14.0	14.8	11.6
	pH	5.1	6.4	7.2	7.1	6.9	7.0	6.6
	Specific Conductance	15.8	21.6	24.2	27.2	28.3	31.6	24.8
Museum Brook	Daily discharge m^3/day	18014	7914	441	683	1166	190	4735
	Total Phosphorus (µg/L)	10.3	9.6	103.0	125.0	42.8	400.0	115.1
	Nitrate/Nitrite-N (µg/L)	155.0	46.2	2146.0	2480.0	354.0	2520.0	1283.5
	Chloride (mg/L)	23.1	15.1	109.0	75.4	56.1	90.2	61.5
	Sodium (mg/L)	13.4	10.3	61.7	50.0	35.2	56.4	37.8
	pH	2.1	3.8	16.3	27.4	20.6	27.9	16.4
	Alkalinity (mg/L)	5.6	5.6	7.0	7.1	6.6	7.4	6.6
	Specific Conductance	84.4	62.2	350.0	279.0	190.2	331.0	216.1
Potter Brook	Daily discharge m^3/day	14161	2670	285	881	432	181	3102
	Total Phosphorus (µg/L)	14.1	10.7	8.1	6.1	7.7	3.0	8.3
	Nitrate/Nitrite-N (µg/L)	403.0	126.0	210.0	185.0	122.0	121.0	194.5
	Chloride (mg/L)	6.0	16.1	56.3	23.7	32.3	69.9	34.1
	Sodium (mg/L)	3.2	10.2	40.6	16.0	20.6	41.0	21.9
	Alkalinity (mg/L)	2.8	8.8	22.6	17.5	18.4	26.6	16.1
	pH	5.1	6.3	6.9	6.9	6.9	6.7	6.5
	Specific Conductance	29.0	73.5	248.0	111.8	124.5	260.0	141.1

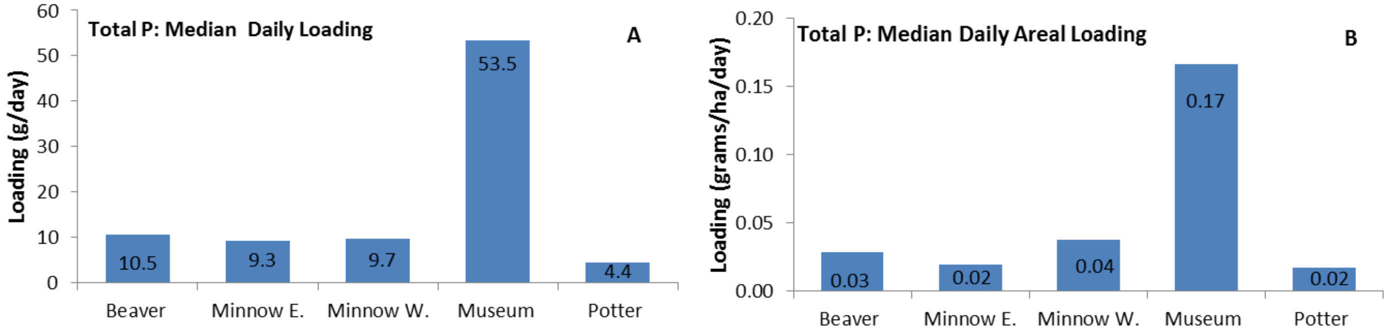

Figure 3. Daily loading of total phosphorus to Blue Mountain Lake from the study streams in 2015-2016. (A) Median daily loading, (B) Median daily loading standardized for watershed area.

The mass of phosphorus loaded to the lake on a daily basis was similar between all watersheds with the exception of Museum Brook (Figure 3a). The median daily loading of phosphorus from Museum Brook was 53.5 grams/day, while it ranged between 4.4 and 10.5 g/day from the other four watersheds. When normalized for watershed area, Museum Brook contributed significantly more phosphorus to the lake at 0.17 grams/ha/day (P = 0.04, H = 10.15) The other four streams all had similar areal loading rates, ranging from 0.02 g/ha/day (Minnow East) to 0.03 g/ha/day (Minnow West: Figure 3b).

Nitrate

Generally speaking, nitrate concentration in the streams was greatest in the spring and lowest during the base flow conditions observed in the August through October. Nitrogen concentration in the form of nitrate ranged from a low of 14.9 µg/L in Minnow Brook East on October 11th, to a high of 2,280 µg/L in Museum Brook on August 1st (Table 2).

The mass of nitrate loaded to the lake on a daily basis was greatest in Museum Brook where we observed a median daily loading rate of 427 µg/L. The median daily loading rate of the other four streams ranged from 39 ug/L/day (Minnow West) to 109 µg/L/day (Minnow East: Figure 4a). When normalized for watershed area, Museum Brook contributed significantly more nitrate to the lake at 1.3 grams/ha/day (P = 0.04, H = 10.15) The other four streams all had similar areal loading rates for nitrogen, ranging from 0.1 g/ha/day (Beaver) to 0.4 g/ha/day (Potter: Figure 4b).

Road Salt Contaminants

The lowest concentrations of sodium and chloride was observed at Minnow Brook West and Beaver Brook, where average concentrations were found to

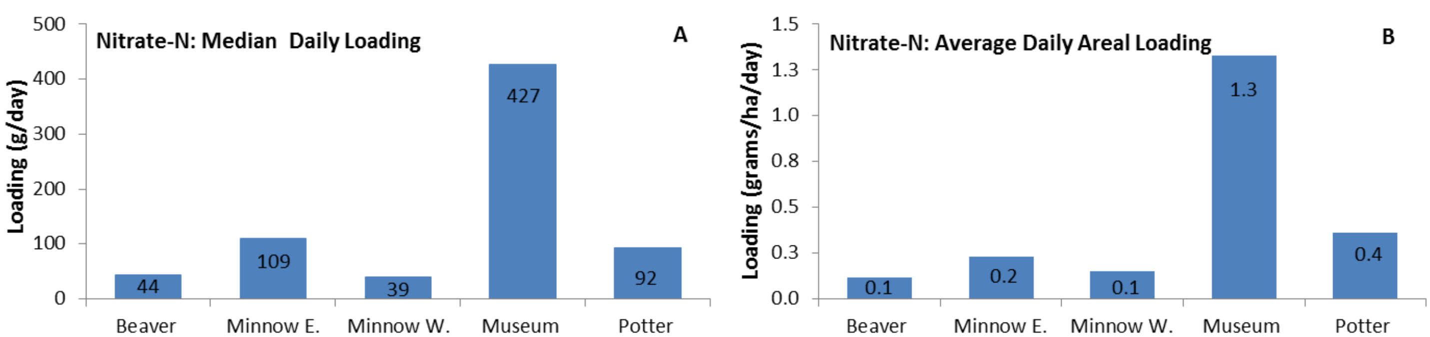

Figure 4. Daily loading nitrate-N to Blue Mountain Lake from the study streams in 2015-2016. (A) Median daily loading, (B) Median daily loading standardized for watershed area.

be 1.0 mg/L for sodium and 0.4 mg/L for chloride at both locations. The greatest average concentration was at Museum Brook (Na: 37.8 mg/L, Cl: 31.5 mg/L), followed by Potter Brook (Na: 21.9 mg/L, Cl: 34.1 mg/L), and Minnow East (Na: 15.7 mg/L, Cl: 21.2 mg/L, Table 2).

We found the mass of road salt contaminants loaded to the lake was lowest for Beaver and Minnow Brook West, the streams with the least amount of roads in their respective watersheds. The median daily load of sodium and chloride in both these streams was 0.8 and 0.3 kilograms/day respectively. Sub-watersheds containing salted roads loaded significantly more of these ions to the lake (Figure 5a). The greatest salt load was observed at Museum brook, where median daily load was 32 kilograms of sodium/day and 51 kilograms of chloride/day. When normalized for watershed area, Museum Brook contributed significantly more sodium and chloride to the lake at 100 and 159 grams/ha/day respectively (Na: $P < 0.001$, $H = 35.4$; Cl: $P<0.001$, $H = 38.3$). The areal loading rate of sodium and chloride at Potter Brook and Minnow West were statistically similar to each other and lower than the flux observed for Museum.

The in-stream Hobo conductivity meters allow us to observe the movement of road salt containments into the lake at a very fine scale (30 minute intervals). The relationship between conductivity and chloride concentration for the Blue Mountain Lake watershed is still in development and will require at least one more year to calibrate. However, the data from the meters allows us to compare the salt flux between subwatersheds (Figure 6). The field conductivity for the least impacted streams, Beaver and Minnow West, is low and typically ranged between 20 and 40 µS/cm across the entire year. Minnow East, Museum, and Potter Brooks are all impacted by salted roads and the movement of the road salt into the lake is apparent in the field conductivity data. Conductivity values were greatest during the spring melting period, and also increased again during summer base flow. For example, in Museum Brook conductivity values as high as 1,600 µS/cm were recorded by the data logger in February of 2016, and were routinely between 400 and 500 µS/cm during the low flow.

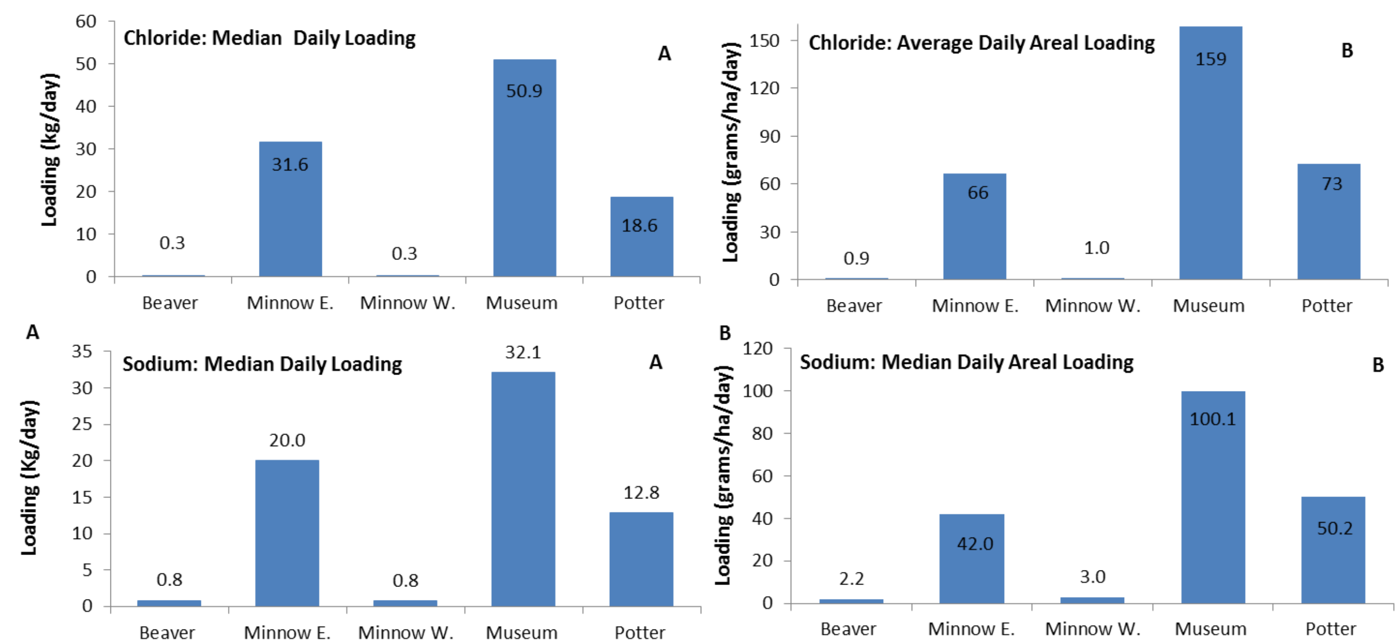

Figure 5. Daily loading of sodium and chloride to Blue Mountain Lake from the study streams in 2015-2016. (A) Median daily loading, (B) Median daily loading standardized for watershed area.

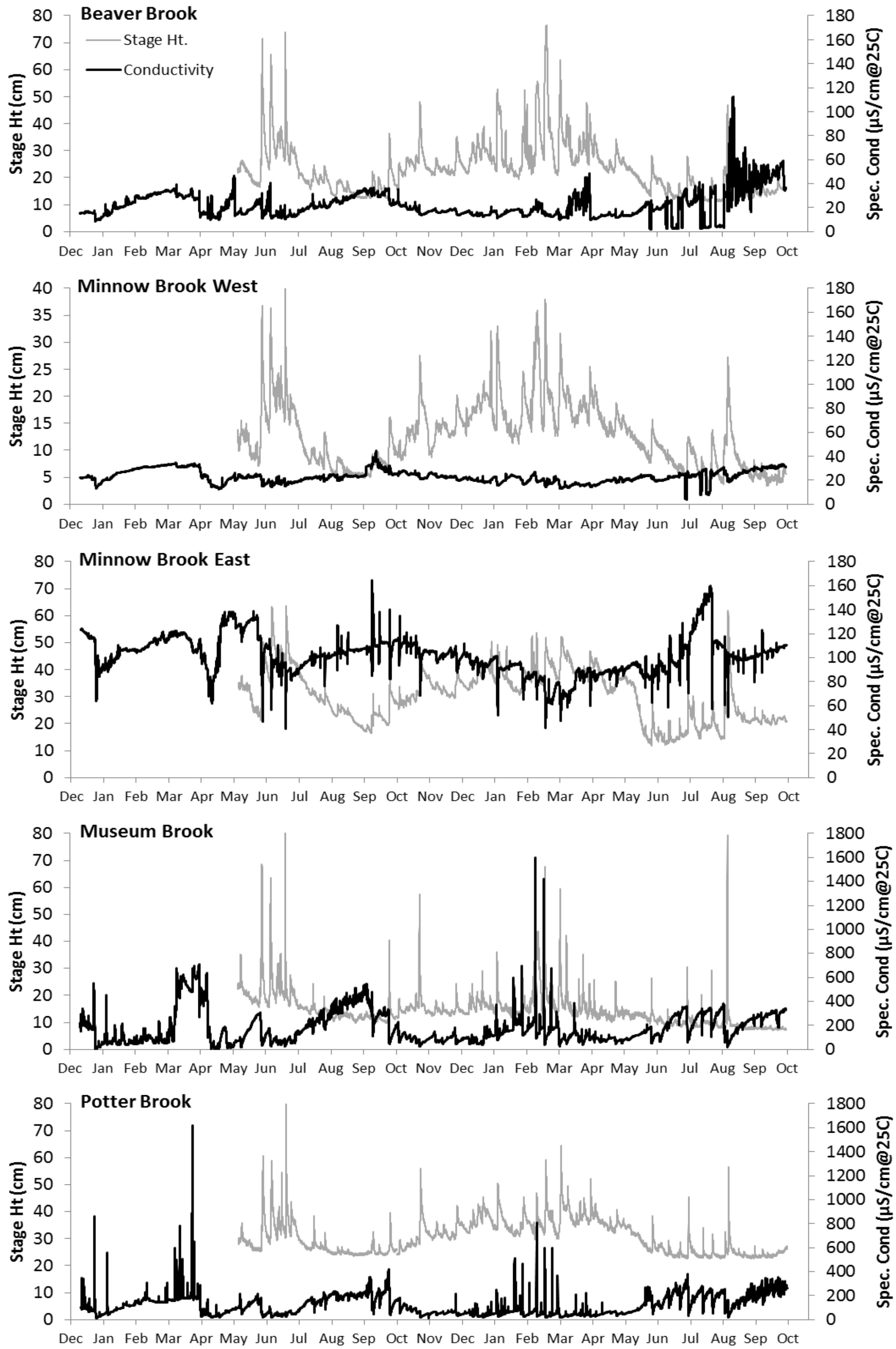

Figure 6. High resolution field conductivity (dark lines) and stage height (grey lines) for the sub-watersheds of Blue Mountain Lake, December 2014 to October 2016.

Discussion

The key to comprehending the water quality of Blue Mountain Lake is an understanding of the chemical inputs from the watershed. Recent evaluation of the water quality of Blue Mountain Lake by Laxson et. al (2017) reinforced the assessment that Blue Mountain Lake is: (1) circumneutral in terms of its acidity, with moderate acid neutralizing ability, (2) oligotrophic, with high transparency and low concentration of phosphorus and other nutrients, and (3) impacted by road runoff, with high concentrations of sodium and chloride.

We found the tributary streams entering Blue Mountain to be acidic during spring runoff and circumneutral during the remainder of the year. This is a common occurrence in the Northeast. Snowpack is acidic, with an average pH of 5.0 at Huntington Forest in the central Adirondacks (National Trends Network 2017). When the snow melts in the spring a flush of acidic meltwater fills the streams. Later in the year the streams are supplied by groundwater, which in most cases has percolated through the soil and acquired acid neutralizing components such as carbonates and dissolved organic matter. Prior to entering the lake, all of the Blue Mountain study streams drain lowland areas or wetlands, these areas provide deeper soils which increases the buffering ability of the water. In addition, the Adirondack Region has experienced an overall decrease in acid deposition (Strock et. al 2014). Data from Huntington Forest reveals that the primary indices of acid deposition, H+ and the acid anions sulfate and nitrate, are all exhibiting significant reductions over the past 26 years (National Trends Network 2017).

Overall, nutrient export from the sounding watershed to Blue Mountain Lake is low. Median phosphorus load ranged from 0.02 to 0.04 grams/ha/day, with the exception of Museum Brook which had five times the export of phosphorus, at 0.17 grams/ha/day. A similar pattern existed for nitrate, the greatest export was at Museum Brook, where a median daily nitrate flux of 1.3 grams/ha/day was observed. The elevated nutrient export observed at Museum Brook is almost certainly related to the permitted discharge from the waste water treatment facility of the Adirondack Museum (SPDES # NY0240273). Analysis of the detailed facility report did not yield any violations of the Clean Water Act through the end of 2016. However, permit limits, monitoring requirements, and loading data from the facility were not available on the EPA Enforcement and Compliance website as we expected them to be (www.echo.epa.gov). Even though the nutrient export from Museum Brook is elevated, it is important to recognize that nutrient export is quite low from all the tributaries of Blue Mountain Lake, even Museum Brook. For comparison purposes, phosphorus export from undeveloped streams of similar size in the St. Regis and Ausable River watersheds during the same time period ranged from 0.01 to 1.9 g/ha/day for phosphorus and 0.01 to 6.1 grams/ha/day for nitrate (AWI unpublished data 2017). Nutrient exports from the Blue Mountain streams are all within the range of unimpacted watersheds for phosphorus, and below the range for nitrate. Streams impacted by agriculture in the Finger Lakes region of New York may export as much as 2.36 g/ha/day of phosphorus and 131 g/ha/day of nitrate (Makarewicz et.al 2009).

The Blue Mountain Lake watershed is significantly influenced by road salt. The concentrations of sodium and chloride in the surface water of the lake are greater than 83% of the waterbodies that participated in the Adirondack Lake Assessment Program in 2016 (Laxson et. al 2017). The elevated salt concentration of the lake is undoubtedly due to saline run off from NYS routes 28 and 30, which drains through the Minnow Brook East, Museum Brook, and Potter Brook sub-watersheds, as well as 587 hectares of land along the lake that is not drained by any specific tributary.

Photo 2, AWI technician Hunter Favreau collecting a sample of direct road runoff from NYS Rt. 28/30 before it entered Museum Brook in March of 2017. This sample contained over 700 mg/L of chloride, which is approximately 1,400 times the concentration of unimpacted surface runoff.

Beaver Brook is the only sub watershed that has no salted roads, and thus serves as a good benchmark for the unimpacted condition. The median export of sodium and chloride from Beaver Brook was 2.2 and 0.9 grams/ha/day respectively, which is similar to the range of unimpacted watersheds in the AWI database. Sub-watersheds of Blue Mountain Lake with salted roads had 70 to 200 times more chloride export. The greatest export was at Museum Brook, where we conservatively estimate that nearly 51 kilograms of chloride were loaded to the lake each day during the monitoring period of 2016. However, this estimate is fairly coarse because it only takes into account the values on the 11 sampling days across two years. Data from the instream conductivity meters indicate that the salt flux in impacted streams is significantly greater during melting periods, and that the pattern is unique for each stream. For example, in Museum and Potter Brook conductivity values as high as 1,600 µS/cm were recorded by the data logger in February and March. Conductivity values in this range are typically associated with chloride concentrations of 525 mg/L, which is approximately 1,300 times greater than the expected runoff from watersheds without roads (AWI: unpublished data). During the low flow period of the summer the field conductivity of Museum Brook was routinely between 400 and 500 µS/cm. Conductivity values in this range are typically associated with chloride concentrations between 100 and 150 mg/L or 375 times greater than background concentration. High concentrations of salt during the low flow periods is indicative of ground water contamination. Full development of the stage discharge curves will allow us to make accurate high resolution estimates of salt load to the lake.

Conclusions

The Blue Mountain Lake Stream Monitoring Program was established primarily to understand the lake itself. The subwatersheds draining into the lake are slightly acidic to circumneutral depending on the time of year and have moderate acid neutralizing capacity. Museum Brook loaded the greatest amount of phosphorus and nitrate to the lake. The source of the elevated nutrients is likely the permitted discharge from the Museum's waste water treatment plant. All of the nutrient loads to the lake are within the range of least impacted streams, which suggest no cause for concern. Road salt runoff has substantially altered the chemistry of three of the five sub watersheds. We estimate the salt loading to the lake from these impacted streams to be 70 to 200 times greater than baseline conditions at a minimum. Development of the stage discharge relationships for the tributary streams will greatly increase our ability to quantify the hydrology and chemical loading to the lake.

Recommendations

Full development of the stage discharge curves will take at least one more year because discharge measurements need to be taken across a variety of stream flows. In addition, accurate loading estimates require numerous samples to be taken and analyzed throughout the year. Therefore, we recommend an increase in sampling frequency from the current program of 5 trips per year (once a month, May - October) to one that includes hydrologic event and non-event sampling throughout the entire year. We believe this increase in sampling intensity can be achieved with little increase in cost through a combination of AWI site visits and volunteer water sampling, or by spreading the sampling trips out evenly across the hydrologic year. We hope to discuss these recommendations further with Water Watch.

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