Acid Rain Monitoring Project

FY10 End of Fiscal Year Report

June 30 2010

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Bureau of Waste Prevention

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Introduction

This report covers the period July 1, 2009 to June 30, 2010, the ninth year of Phase IV of the Acid Rain Monitoring Project. Phase I began in 1983 when about one thousand citizen volunteers were recruited to collect and help samples from nearly half the state's surface waters. In 1985, Phase II aimed to do the same for the rest of the streams and ponds in Massachusetts. The third phase spanned the years 1986-1993 and concentrated on a subsample of streams and ponds to document the effects of acid deposition to surface waters in the state. Over 800 sites were followed in Phase III, with 300 citizen volunteers collecting samples and doing pH and ANC analyses. In 2001, the project was resumed on a smaller scale: about 50 volunteers are involved to collect samples from approximately 150 sites, 26 of which are long-term sites with ion and color data dating back to Phase I. In Phase IV (2001-2003), 161 lakes were monitored for 3 years. Since fall 2003 (Phase V), the project has been monitoring 151 sites, mostly streams, except for the 26 long-terms sites which are predominantly lakes.

Goals

The goals of this project are to determine the overall trend of sensitivity to acidification in Massachusetts surface waters and whether the 1990 Clean Air Act Amendment has resulted in improved water quality.

Methods

Methods were mostly unchanged from previous years: Volunteer collectors are contacted a month before the collection to confirm participation. Clean sample bottles are sent to them in the mail or via UPS, along with sampling directions, a field sheet/chain of custody form, and directions to the sampling sites if necessary. Collectors visit their site(s) twice a year, in April and October, when they collect a surface water sample from the bank or wading a short distance into the water body. They collect upstream of their body after rinsing their sample bottle 3 times with sample lake or stream water. If collecting by a bridge, they collect upstream of the bridge unless safety and access do not allow it. They fill in their field data sheet with date, time, site code information, place their samples on ice in a cooler and deliver the samples to their local laboratory right away. They are instructed to collect their samples as close to the lab analysis time as possible. In a few cases, samples are collected the day prior to analysis because the lab is not open on traditional "ARM Sunday." Previous studies by our research team has established that pH does not change significantly when the samples are refrigerated and stored in the dark.

Volunteer labs are sent any needed supplies (sulfuric acid titrating cartridge, electrode, buffers), 2 quality control (QC) samples, aliquot containers for long-term site samples, and a lab sheet one week to ten days before the collection. They analyze the first QC sample in the week prior to the collection and call in their results to the Statewide Coordinator. If QC results are not acceptable, the volunteer analyst discusses possible reasons with the Statewide Coordinator and the Lab Director and makes modifications until the QC sample gives acceptable results. On Collection day, volunteer labs analyze the second QC sample before and after the regular samples, and report the results on their lab sheet along with the regular samples. Analyses are done on their pH-meters with KCl-filled combination pH electrodes. Acid neutralizing capacity (ANC) is measured with a double end-point titration to pH 4.5 and 4.2. Most labs use a Hach digital titrator for the ANC determination, but some use traditional pipette titration equipment. Aliquots are taken from the 26 long-term sites to fill one 60mL bottle and one 50mL tube for later analysis of ions and color. These aliquots are kept refrigerated until pick-up from UMass staff.

Aliquots, empty bottles, and results are collected by ARM staff a day or two after the collection. The Cape Cod lab mails those in, with aliquot samples refrigerated in a cooler with dry ice.

The Statewide Coordinator reviews the QC results for all labs and flags data for any lab results that do not pass Data Quality Objectives (within 0.3 units for pH and within 3mg/L for ANC). pH and ANC data are entered by one ARM staff and proofed by another. Data are uploaded into the web-based database at http://umatei.tei.umass.edu/ColdFusionProjects/AcidRainMonitoring/ and posted on the ARM web page at http://www.umass.edu/tei/wrrc/arm/.

Aliquots for 26 long-term sites are analyzed for color on a spectrophotometer within one day; anions within one month on an Ion Chromatograph; and cations within 6 months (but usually 2 months) on an ICP at the Environmental Analysis Lab (EAL) on the UMass Amherst campus. The data is sent via MS Excel spreadsheet to the Statewide Coordinator who uploads it into the web-based database.

UMass Chemistry Department's Dr. Julian Tyson and his laboratory team of graduate students run the Environmental Analysis Lab (EAL) and provide the QC samples for pH and ANC to all of the volunteer labs. EAL also provides analysis for pH and ANC for selected sampling sites.

Accomplishments

1. Monitoring was completed for 23 and 25 of our long-term group of 26 lakes and streams for pH, ANC, color and ions for the October 25, 2009 and the April 11, 2010 collections, respectively. Analysis results are presented in Tables 6 and 7 (see Appendix).

2. An additional 127 statistically representative streams were sampled to measure statewide trends in acidification (pH and ANC only). Analysis results are presented in Table 8 (see Appendix).

3. The network of volunteers was maintained and kept well informed on the condition of Massachusetts surface waters so that they would be able to participate effectively in the public debate. This was accomplished by e-mail and telephone communication, as well as through updates via an internet list-serv.

   There were 11 volunteer labs across the state, in addition to the EAL at UMass Amherst, in charge of pH and ANC analyses (Table 4).

   Table 1: Volunteer Laboratories

Analyst Name	Affiliation	Town
Joseph Ciccotelli	Ipswich Water Treatment Dept	Ipswich
Alan Christian	UMass Boston Environmental Studies Program	Boston
Cathy Wilkins	Greenfield High School	Greenfield
Sherrie Sunter	MDC Quabbin Lab	Belchertown
Dave Bennett	Cushing Academy	Ashburnham
Holly Bailey	Cape Cod National Seashore	South Wellfleet
Robert Caron	Bristol Community College	Fall River
Bob Bentley	Analytical Balance Labs	Carver
David Doe	Biology Dept. Wilson Hall WSC	Westfield
Jim Bonofiglio	City of Worcester Water Lab	Holden
Carmen DeFillippo	Pepperell Waste Water Treatment Plant	Pepperell
Chengbei Li	University of Massachusetts Environmental Analysis Lab	Amherst

   Several volunteer collectors were also recruited to replace retiring or ill collectors. As in the past, our volunteers take their responsibilities very seriously and take great pride in doing the job in full, revisiting a site if necessary. Some of our volunteers have been with the project since 1982 and are now quite advanced in age but are extremely dedicated and their experience is valuable to the project.

   A total of 72 volunteers participated in this year's program, 49 of them participating in both collections. Sixty-three of the volunteers were collectors, 12 were lab analysts, and 3 were both.

4. The ARM web site and searchable database were maintained and updated, adding new data as it became available. pH, ANC, ions and color data were added to the web database via the uploading tool created in previous years. The database was evaluated for quality control and uploading errors were corrected. The web-based program was updated to include recent years.

5. The data collected was analyzed for trends in pH and ANC for 151 sites and for color and ions for 26 sites, using the JMP® Statistical Discovery Software (http://www.jmp.com/software/). Bivariate

analyses (scatter plots, regression, and correlation) were run on pH, ANC, each ion, and color separately, predicting concentration vs. time. We looked at the data set for all seasons and for April and October separately to see if trends were dependent on season. Standard t-tests were also run on the same groups of data, comparing the current 10 years of data (2001-2010) to the older 10 years of data (1983-1993). We should note that the historical data includes collections from all months of the year rather than just April and October which are the only months we sampled in the latest phase of the project. This explains why statistics for the whole set of data are sometimes somewhat different from the results shown in separating the data into two seasons ("April" vs "October").

Data Analysis Results

pH and ANC

Bivariate analysis for pH and ANC

Table 2 displays the number of sites out of 151 that show a significant change over time for pH or ANC. If the difference was not statistically significant (p>0.05), the sites are tabulated in the 'No Change' (not significantly different) category.

Table 2: Bivariate analysis results for pH and ANC

	All seasons		April		October	
	pH	**ANC**	**pH**	**ANC**	**pH**	**ANC**
No Change	96	120	92	105	116	123
Increased	48	22	58	44	18	15
Decreased	7	9	1	2	17	13

Table 3 displays the results of the t-test analysis, showing how many sites have a significant change in the current period compared to historical data.

Table 3: Standard t-test results for pH and ANC

	All Seasons		April		October	
	pH	ANC	pH	ANC	pH	ANC
No Change	101	113	105	107	124	125
Increased	42	21	44	44	15	15
Decreased	8	17	2	0	12	11

Those results are also graphed in figures 1 and 2.

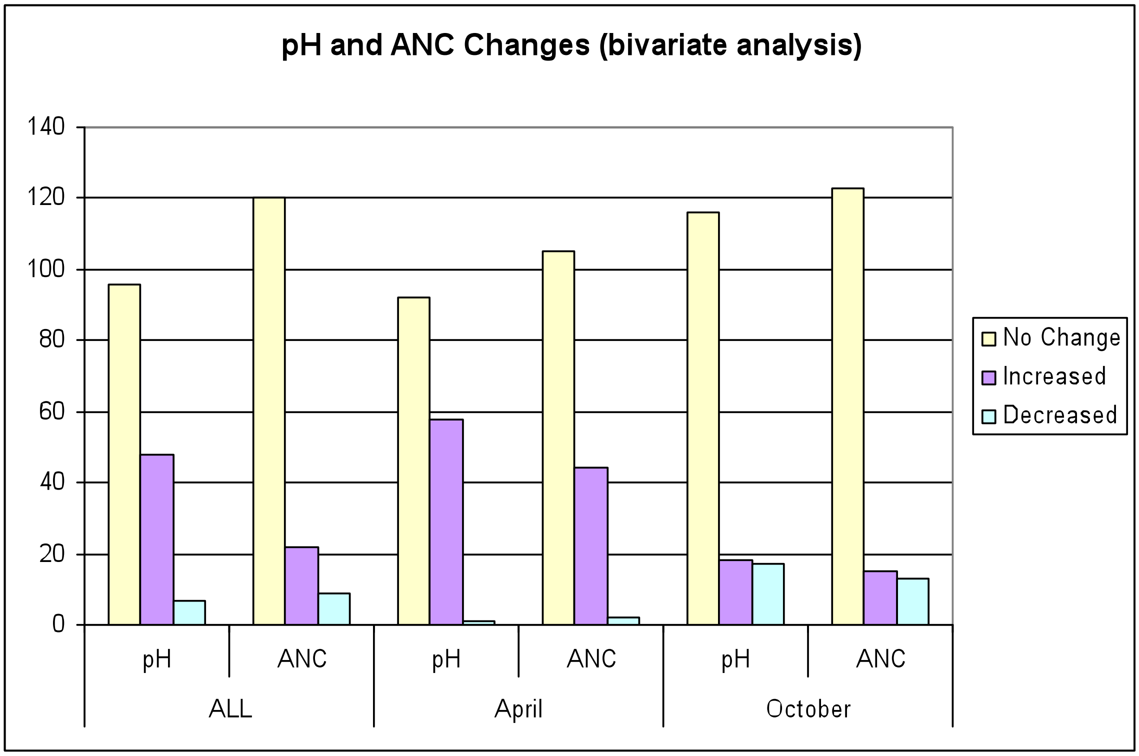


Figure 1. Changes in pH and ANC, from bivariate analysis

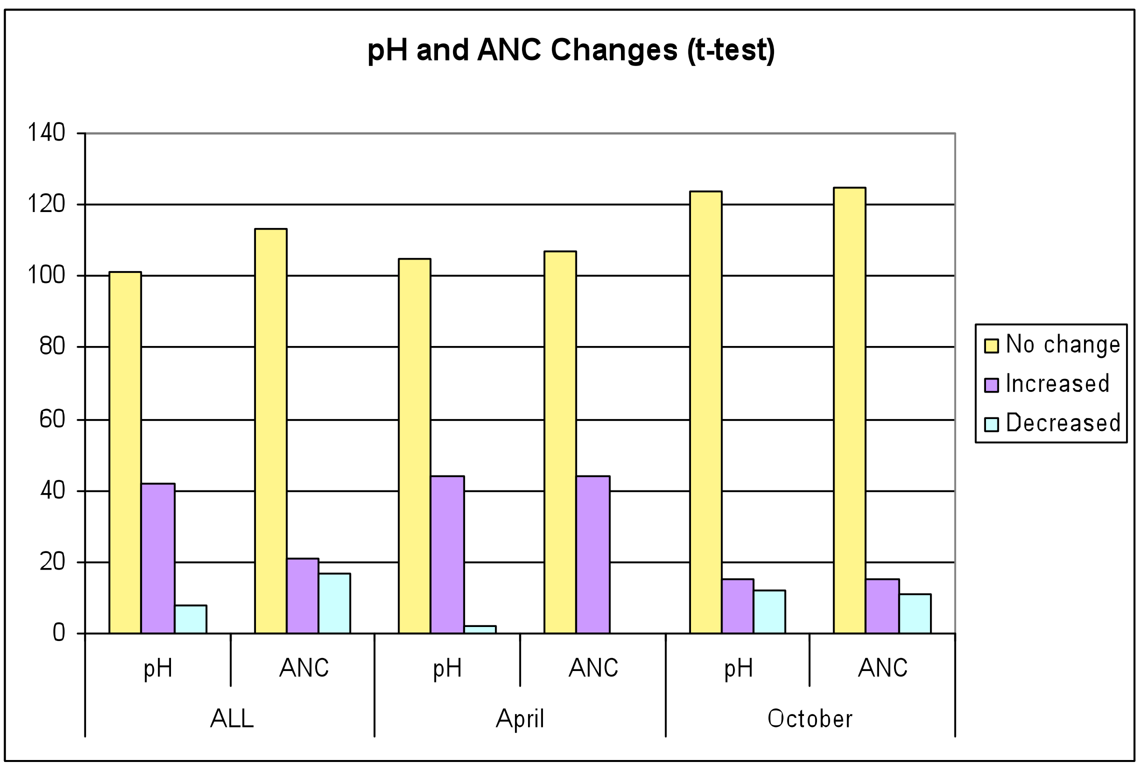


Figure 2. Changes in pH and ANC, from t-test analysis

While both types of statistical analysis give somewhat different results, they both show a similar tendency that for most sites, neither pH nor ANC has changed significantly over time. However, for those sites that show a significant change, more show an increase than a decrease in value. That is especially true for pH, with almost one third of the sites showing a statistically significant increase. ANC shows a less clear trend, except when spring and fall seasons are analyzed separately. In that case, many more sites show an increase in ANC in April than in October.

Ions and Color
Bivariate and standard t-test analyses were run on the 26 long-term sites that are analyzed for 10 ions and color. (In Phase V we analyze 11 ions, but Cu was not part of the cation suite in Phases I through III so no comparison can be made for that ion).

Table 4 and figure 3 show the results of the bivariate analysis for all parameters, while table 5 and figure 4 show the results of the standard t-test analysis.

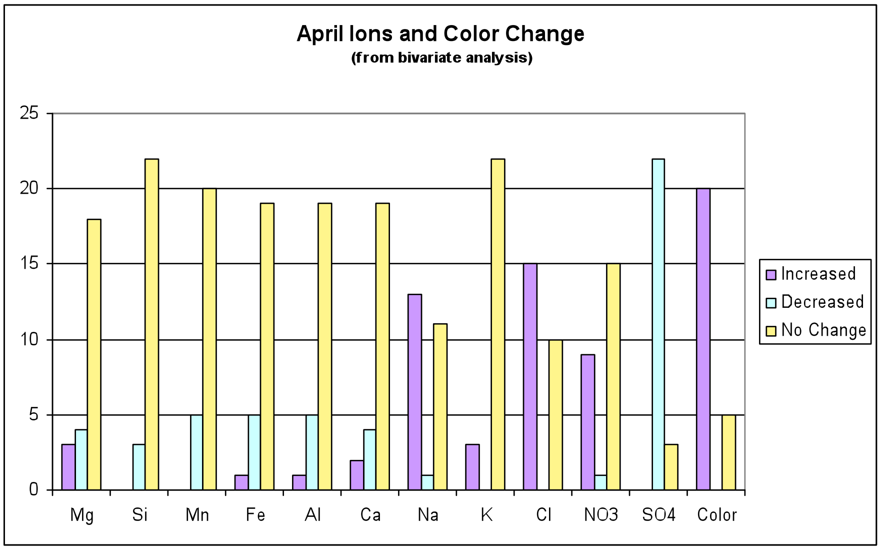
Table 4: Bivariate analysis results for ions and color

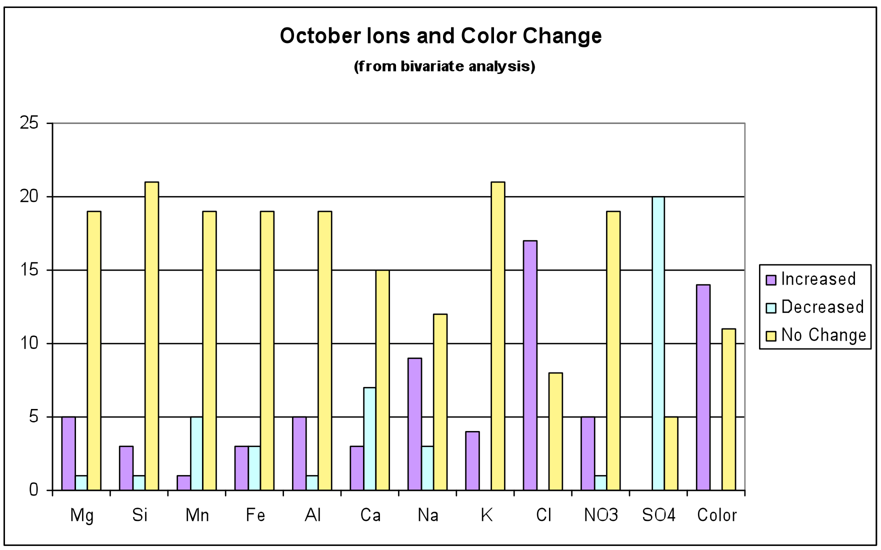
	April			October			All Seasons		
	No Change	Increased	Decreased	No Change	Increased	Decreased	No Change	Increased	Decreased
Mg	18	3	4	19	5	1	19	3	3
Si	22	0	3	21	3	1	23	1	1
Mn	20	0	5	19	1	5	19	1	5
Fe	19	1	5	19	3	3	18	4	3
Al	19	1	5	19	5	1	19	4	2
Ca	19	2	4	15	3	7	14	4	7
Na	11	13	1	12	9	3	12	12	1
K	22	3	0	21	4	0	22	3	0
Cl	10	15	0	8	17	0	6	19	0
NO3	15	9	1	19	5	1	14	10	1
SO4	3	0	22	5	0	20	8	0	17
Color	5	20	0	11	14	0	8	17	0

Table 5: T-test analysis results for ions and color

	April			October			All		
	No change	Increased	Decreased	No change	Increased	Decreased	No change	Increased	Decreased
Mg	19	4	2	20	2	3	18	3	4
Si	21	2	2	21	3	1	22	2	1
Mn	18	1	6	18	1	6	19	1	5
Fe	19	3	3	22	2	1	21	2	2
Al	23	1	1	21	1	3	20	2	3
Ca	15	5	5	18	3	4	16	3	6
Na	12	11	2	11	13	1	10	14	1
K	23	2	0	21	4	0	7	18	0
NO3	22	2	1	13	9	3	14	1	10
SO4	6	2	17	3	2	20	6	0	19
Color	14	10	1	6	19	0	8	17	0

Figure 3: Results of bivariate analysis for ions and color, all seasons, April, and October.





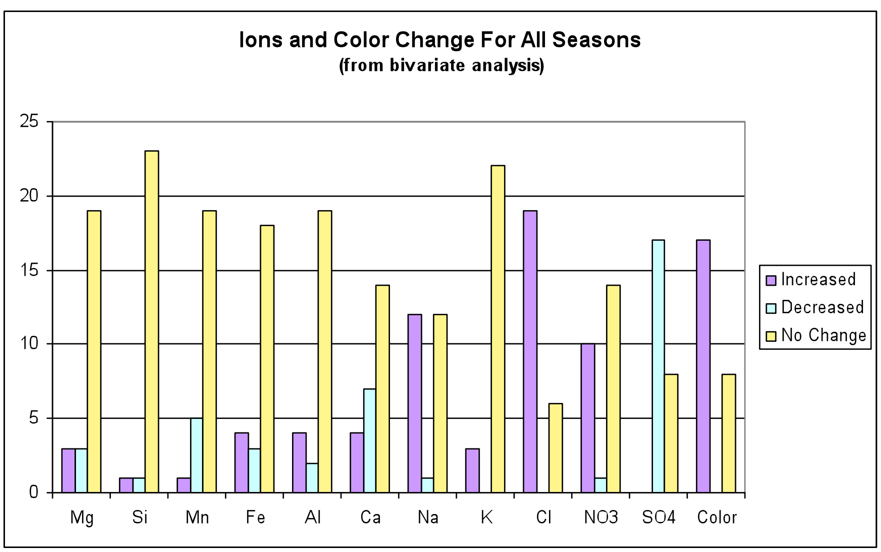
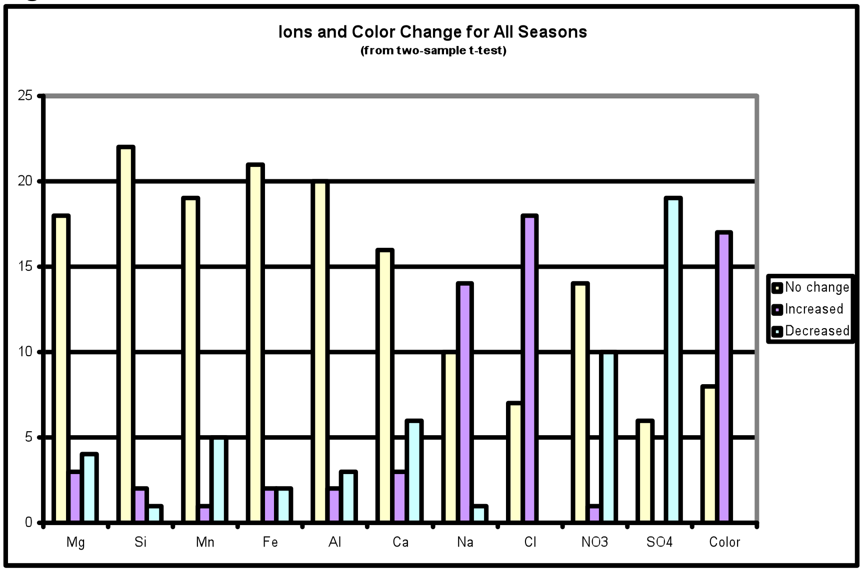
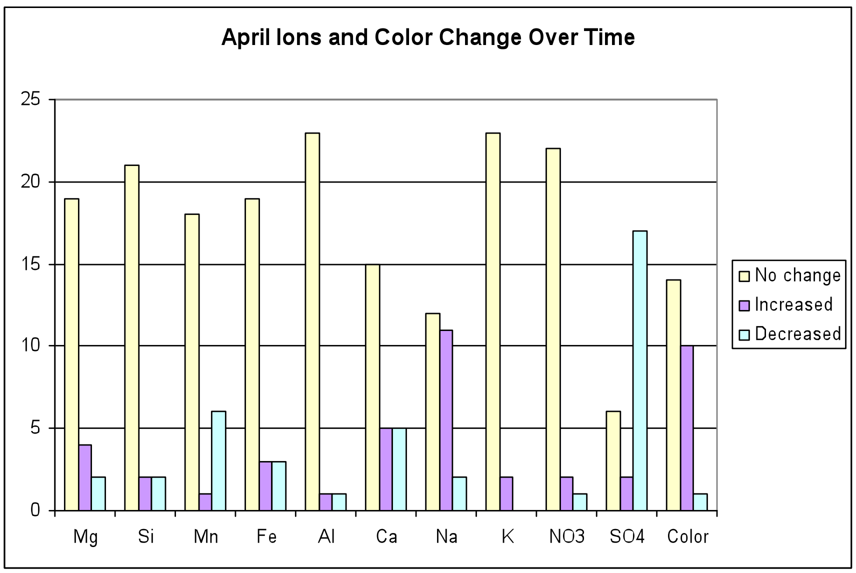
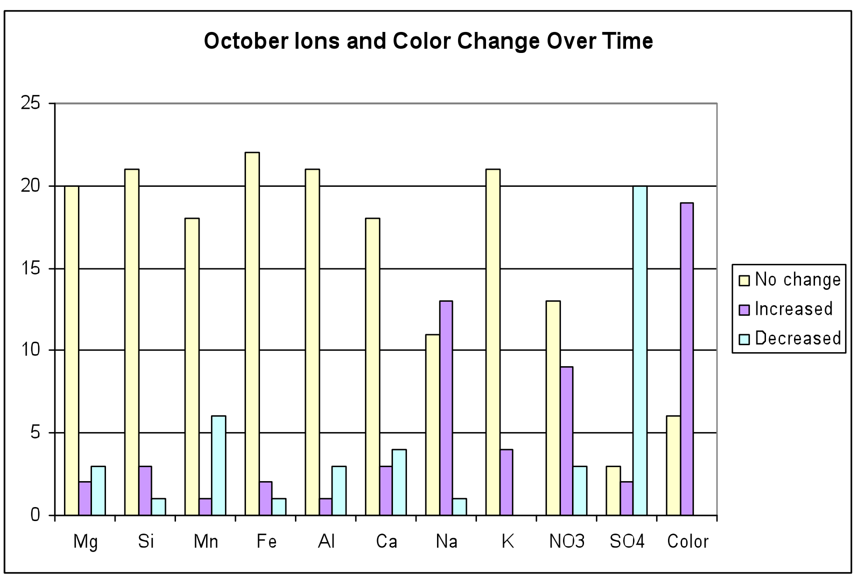


Figure 4: Results of standard t-test for ions and color, all seasons







Most cations show no significant change over time for the 26 sites we are following. A notable difference, however, can be seen for sodium, which increased for almost half of the sites no matter what season and with both types of statistics used.

All anions show significant changes as well. This change is seen more clearly with the bivariate analysis, which tracks concentrations continuously over time, while the t-test compares only the set of data from the first 10 years with the last 10 years of the project. Chloride never decreases with time, and increases for two-thirds of the sites. Nitrate's change is less definite, but it clearly increases for about a third of the sites and decreases for a couple of sites on average. Sulfate shows the most dramatic change, a strong decrease for over two-thirds of the sites.

Color also shows a consistent increase over time, for over two-thirds of the sites in all seasons.

Discussion

These results are mostly consistent with what we found for an earlier analysis we performed on lakes in Phase IV of this project, and with results from other research studies in the northeast. The main difference is that we now see more of an increase in pH, and we are seeing a clearer increase in nitrate in Phase V.

It is interesting to note that for both pH and ANC, more sites show an increase in April than in October, and this trend holds with both statistical tests performed. April is the time of year when we typically see the lowest pH and ANC values, most probably due to snowmelt waters that carry an important amount of nitrates into surface waters. Yet we do not see a clear corresponding trend with nitrate. On the contrary, the bivariate analysis shows more of an increase in nitrate in April than in October, though the reverse is true with the t-test analysis. An explanation might be that the reduction in sulfate is more important than the increase in nitrate, but further research or literature review should be done in order to draw a confident conclusion.

Base cations calcium and magnesium still show no sign of recovery, if anything calcium actually seems to be still declining.

Sulfate continues to show a strong and significant decline, in line with decreases in emissions of sulfur dioxide that followed the 1990 Clean Air Amendment. The increase in nitrate is also not surprising, despite a similar decrease in NOx emissions from power plants, because nitrogen emissions from vehicle sources have increased over time. Since roads in Massachusetts are often located along streams, and because roads are designed to channel water off and away from their surface, increased NOx emissions have a direct path into surface waters.

At this time we cannot confidently assess an increase or a decline in aluminum.

However, we continue to document a significant increase in sodium and especially chloride. This results very likely from road salting practices in the northeast.

The obvious increase in color is less intuitive to explain, but in New England, there is a buffer other than ANC that is rarely considered - organic acids. These natural acids make waters somewhat acidic and tea brown in color, and they act as buffers against further lowering of the pH by mineral acids. So naturally colored waters have been titrating acid deposition and becoming less colored. The increase in color we are observing would point to an increase in buffering capacity that is not measured by ANC.

In conclusion, to answer our question whether the 1990 Clean Air Act Amendment has resulted in improved water quality in Massachusetts surface waters, the answer is a cautious "somewhat." More water bodies seem to have improved than worsened, but the increase in nitrates, coupled with the lack of increase in calcium and magnesium cause concern that the improvement may not last and may even reverse in the future if NOx emissions are not curbed.

It is our recommendation to pursue this long-term monitoring of surface waters in the Commonwealth. We propose to change our sampling scheme to drop half of the streams we are currently following, and replacing them with an equal number of lakes that were monitored in Phase IV.

Acknowledgements

Thank you to all of the project's volunteers who make this project possible by collecting samples all over the state under any weather conditions, and who spend many hours in the lab analyzing samples.

Appendix

Table 6: October 2009 ARM Color and Ion Data

Name	Palsite	Color	Cl	NO3_N	SO4	Mg	Si	Mn	Fe2	Cu	Al	Ca	Na	K
Shingle Island Brook	188	686	12.649	0	2.919	1.07	5.87	0.01	1.01	0.09	0.68	2.18	7.06	1.90
Belmont Reservoir	21010	196	1.397	0	3.968	1.14	2.22	0.0025	0.01	0.15	0.33	3.27	0.60	1.29
Cobble Mt. Reservoir	32018	45	16.353	0.009	3.537	1.12	2.12	0.0025	0.01	0.11	0.20	2.73	9.58	1.11
Hawley Reservoir	34031	827	8.213	0	4.625	0.61	4.77	0.0025	0.17	0.10	0.41	2.30	4.81	1.58
Wyola Dam	34103	NS	NS	NS	NS	0.46	1.04	0.0025	0.07	0.09	0.21	1.65	4.71	1.02
Upper Naukeag Lake	35090	16	12.996	0	3.154	0.37	0.12	0.0025	0.04	0.09	0.31	0.89	8.41	0.94
Crystal Lake	36043	49	1.29	0	1.592	0.27	0.01	0.0025	0.01	0.10	0.22	0.38	0.26	1.34
Lake Lorraine	36084	4	31.121	0	4.029	0.80	0.01	0.0025	0.01	0.09	0.19	3.66	19.28	1.69
Quabbin Station	36129	21	8.186	0	4.432	0.59	0.48	0.0025	0.01	0.09	0.24	2.06	4.78	1.05
Nipmuck Pond	42039	69	19.793	0	4.668	0.52	2.53	0.0025	0.01	0.09	0.36	1.83	11.63	0.88
N. Watuppa Lake	61004	270	18.856	0	2.953	0.75	2.55	0.0025	0.32	0.09	0.40	1.79	10.60	1.11
Ashby Reservoir	81001	95	19.329	0	3.888	0.75	1.78	0.0025	0.49	0.09	0.31	2.35	12.24	1.68
Wright Pond	81160	167	10.187	0	2.646	0.49	1.05	0.0025	1.19	0.09	0.35	1.51	6.44	1.35
Whitehall Reservoir	82120	57	22.634	0.007	3.946	1.00	0.01	0.0025	0.01	0.09	0.27	2.73	12.58	1.28
Hedges Pond	94065	33	11.628	0	4.152	1.09	0.01	0.0025	0.01	0.09	0.23	0.70	6.78	1.17
College Pond	95030	35	6.244	0	3.632	0.73	0.08	0.0025	0.01	0.11	0.13	0.92	3.82	1.01
Ezekiel Pond	95051	42	26.018	0.015	4.958	1.21	0.01	0.0025	0.01	0.10	0.22	1.76	14.93	1.62
Little Sandy Pond	95092	305	19.625	0	3.247	1.01	0.98	0.0025	0.22	0.10	0.62	1.28	11.16	1.93
Great Pond	96117	7	28.617	0	6.661	1.97	0.01	0.0025	0.01	0.10	0.20	1.24	15.67	1.51
Kinnacum Pond	96163	115	17.759	0	3.287	1.15	0.01	0.0025	0.01	0.09	0.23	0.30	8.95	1.27
Caldwell Creek	3626575	99	7.541	0	4.456	0.61	4.45	0.0025	0.10	0.12	0.37	1.82	4.14	1.30
W. Branch Swift River	3626800	279	13.419	0.007	3.586	0.79	2.91	0.0025	0.37	0.09	0.32	2.76	7.42	1.97
E. Branch Swift River	3627200	438	7.1	0	3.543	0.69	5.41	0.0025	0.61	0.09	0.66	1.28	4.01	1.40
Rattlesnake Brook	6235125	577	14.09	0	2.869	1.14	5.43	0.0025	0.49	0.20	0.75	1.78	7.20	1.83
Angeline Brook	9560000	753	39.981	0	3.897	1.59	5.50	0.0025	0.94	0.14	0.60	4.34	23.23	3.40
Bread & Cheese Brook	9560150	686	12.649	0	2.919	1.07	5.87	0.01	1.01	0.09	0.68	2.18	7.06	1.90

NS = No Sample

Table 7: April 2010 ARM Color and Ion Data

Name	Palsite	Color	Cl	NO3_N	SO4	Mg	Si	Mn	Fe2	Cu	Al	Ca	Na	K
Shingle Island Brook	188	385.00	11.49	0.06	5.60	0.86	2.35	0.09	0.52	0.01	0.23	2.32	6.99	1.36
Belmont Reservoir	21010													
Cobble Mt. Reservoir	32018	75.50	14.74	0.06	3.72	0.90	2.69	0.02	0.11	0.01	0.02	2.28	8.87	0.58
Hawley Reservoir	34031	42.00	10.49	0.03	5.54	0.52	4.45	0.03	0.08	0.01	0.08	2.27	6.32	0.49
Wyola Dam	34103		6.40	0.01	4.38	0.36	2.46	0.02	0.05	0.00	0.06	1.55	4.29	0.48
Upper Naukeag Lake	35090	46.50	14.09	0.01	3.11	0.27	0.83	0.01	0.04	0.01	0.06	0.87	9.07	0.37
Crystal Lake	36043	30.00	1.14	0.01	2.30	0.23	0.02	0.03	0.05	0.01	0.05	0.61	0.59	0.48
Lake Lorraine	36084	7.50	33.85	0.03	4.40	0.72	0.02	0.01	0.03	0.01	0.01	3.70	21.28	1.10
Quabbin Station	36129													
Nipmuck Pond	42039	27.00	16.72	0.01	5.13	0.36	2.72	0.02	0.03	0.01	0.18	1.61	10.45	0.39
N. Watuppa Lake	61004													
Ashby Reservoir	81001	86.00	12.62	0.01	4.00	0.50	1.42	0.03	0.27	0.02	0.01	1.81	8.71	0.69
Wright Pond	81160	101.50	7.64	0.01	2.87	0.31	1.23	0.03	0.33	0.00	0.10	1.14	5.28	0.59
Whitehall Reservoir	82120	56.00	19.42	0.01	4.69	0.78	0.36	0.01	0.08	0.01	< DL	2.71	11.56	0.81
Hedges Pond	94065	26.00	12.22	0.01	4.21	0.97	0.28	0.00	0.01	0.01	0.01	0.83	6.87	0.55
College Pond	95030	30.00	6.21	0.01	3.53	0.67	0.47	0.01	0.03	0.03	< DL	0.85	4.01	0.46
Ezekiel Pond	95051	44.00	24.20	0.01	4.51	1.06	0.11	0.00	0.05	0.01	0.01	1.78	13.91	0.87
Little Sandy Pond	95092	47.50	22.16	0.07	3.78	0.93	0.05	0.01	0.04	0.01	0.01	1.29	12.47	1.27
Great Pond	96117	11.00	27.39	0.01	6.62	1.83	0.05	0.03	0.03	0.01	< DL	0.97	15.10	0.79
Kinnacum Pond	96163	89.00	18.39	0.01	2.93	1.21	0.06	0.03	0.04	0.01	0.06	0.50	10.10	0.75
Caldwell Creek	3626575	38.00	6.85	0.01	5.30	0.47	4.15	0.02	0.04	0.01	0.09	1.64	4.67	0.26
W. Branch Swift River	3626800	101.00	11.24	0.05	4.68	0.55	2.32	0.05	0.26	0.01	0.07	2.27	7.20	0.83
E. Branch Swift River	3627200	203.50	6.76	0.01	5.49	0.43	3.26	0.03	0.21	0.01	0.17	1.05	4.77	0.49
Rattlesnake Brook	6235125	358.00	10.06	0.03	3.52	0.93	1.82	0.01	0.31	0.02	0.32	1.88	6.03	1.16
Angeline Brook	9560000	428.50	38.73	0.42	5.33	1.32	3.27	0.04	0.50	0.05	0.24	3.88	23.27	1.61
Bread & Cheese Brook	9560150	385.00	11.49	0.06	5.60	0.86	2.35	0.09	0.52	0.01	0.23	2.32	6.99	1.36

NS = No Sample
< DL = Below Detection Limit

Table 8: pH and ANC, all sampling sites.

		October 2009		April 2010	
PALSITE	NAME	PH	ALK	PH	ALK
5131425	Aldrich Brook	6.22	5.2	6.31	4.22
9560000	Angeline Brook	4.57	-2.8	5.48	0.7
2105425	Anthony Brook	6.70	5.9	6.76	5.1
81001	Ashby Reservoir	6.55	4.2	6.64	3.2
3626700	Atherton Brook	5.24	0.3	6.1	0.7
3107625	Babcock Brook	6.99	9.2	6.16	4.3
3417750	Bagg Brook	NS	NS	8.1	79.5
3523925	Bailey Brook	7.85	-0.3	6.08	3.7
3524050	Baker Brook	5.43	5.4	5.64	1.6
8146000	Bartlett Pond Brook	5.71	1.5	5.61	0.5
2105350	Barton Brook	7.18	22.2	7.72	44.9
6236100	Bassett Brook	5.51	1.3	6.05	3.4
371.0001	Beagle Club Pond	5.91	7.1	6.6	4.2
3523825	Beaman Brook	6.11	1.8	5.75	0.9
3627475	Beaver Brook	6.90	10.44	6.84	10.1
6235800	Beaver Brook	6.11	8.8	6.62	10.7
9458025	Beaver Dam Brook	5.90	5.3	6.35	8.3
6236250	Beaverdam Brook	4.46	-3	4.71	0
21010	Belmont Reservoir	6.79	7.6	6.98	12.8
3107375	Benton Brook	6.22	4.8	6.41	6.6
2105750	Bilodeau Brook	7.02	20.3	7.16	22.5
8144075	Bixby Brook	6.45	6.35	6.55	4.1
3522675	Black Brook	6.47	3.1	6.19	1.9
6237625	Black Brook	5.43	2.1	6.03	0.2
9253700	Black Brook		20.9	6.78	15.1
6134700	Blossom Brook	4.45	-1.9	4.52	-1.8
3524375	Bluefield Brook	4.87	-0.2	4.67	-1.5
9253925	Boston Brook		19.5	6.91	16.6
3523400	Boyce Brook	5.69	0.8	5.99	0.6
3315325	Bozrah Brook	7.45	17.4	7.16	13.1
9560150	Bread And Cheese Brook	6.04	4.5	6.13	3
9153000	Bull Brook		16.6	6.59	12
5233750	Bungay River	NS	NS	6.72	15.6
3628075	Burnshirt River	NS	NS	5.98	7.4
3627850	Burrow Brook	NS	NS	6.15	1.28
3626575	Cadwell Creek	5.69	0.65	5.99	8.6
2105725	Cady Brook	6.82	10.2	6.8	14
5334150	Clear Run Brook	5.69	3.5	7.58	75.9
7239175	Clematis Brook	NS	NS	6.7	30.2
5132550	Coal Mine Brook	7.59	36.5	NS	NS
32018	Cobble Mountain Reservoir	6.77	5.5	6.58	3.8
6134550	Cole River	6.69	7.1	6.72	11.3
95030	College Pond	6.31	1.2	6.47	2.6

7240050	Cress Brook		32.1	6.44	13.5
5132625	Cronin Brook	6.42	9	6.89	8.1
36043	Crystal Lake	5.45	0.2	5.61	4.2
6235925	Dam Lot Brook	5.48	1.5	6.24	4.6
3419600	Dean Brook	4.99	-0.5	6.05	0.8
7240225	Dix Brook		14.1	6.07	14
5132700	Dorothy Brook	7.01	30.5	NS	NS
2103800	Dry Brook	7.15	46.1	7.54	110.5
3627200	East Branch Swift River	6.53	4.26	6.46	28
3314925	East Oxbow Brook	7.02	5.6	6.76	5.5
3420100	Esther Brook	7.34	31.6	7.44	20.2
95051	Ezekiel Pond	6.14	2.3	6.47	0.6
6235375	Fall Brook	5.49	2	5.72	1.7
3627500	Flat Brook	6.41	9.51	6.51	80.4
3106825	Fox Brook	6.72	6.3	6.22	2
4230075	French River	6.94	13.5	6.43	7.98
7240375	Godfrey Brook	6.93	33.5	NS	NS
96117	Great Pond	5.20	-0.4	5.105	-0.2
8143775	Greens Brook	6.5	50.9	7.22	36.2
3420000	Ground Brook	7.23	24.1	7.67	30.3
8143675	Gulf Brook	6.94	30.2	7.13	9.35
3210425	Hamilton Brook	6.56	4.8	6.51	3
3315075	Hartwell Brook	7.48	23.2	7.54	21.3
9661525	Hatches Creek	6.21	9.2	6.16	6.6
34031	Hawley Reservoir	5.91	1.89	6.02	11.8
94065	Hedges Pond	5.81	1.4	5.99	1.2
3313175	Hinsdale Brook	7.71	52.4	7.92	52.7
3627000	Hop Brook	6.39	3.2	6.7	4.4
9253500	Ipswich River		24.5	6.85	19.4
8143925	James Brook	6.74	42.8	7.03	50.8
3523750	Kenny Brook	6.00	1.7	6.11	1.3
6134500	Kickamuit River	5.80	4.6	6.49	6
3421725	Kidder Brook	6.63	3.3	6.67	2.5
2105700	Kilburn Brook	6.78	5.2	6.94	7.9
9253625	Kimball Brook		18.6	7	19.8
6134725	King Phillip Brook	4.36	-2.4	4.5	-1.8
96163	Kinnacum Pond	4.95	-0.5	4.82	-0.8
3314450	Kinsman Brook	7.12	11.6	7.26	12.5
36084	Lake Lorraine	6.94	9	6.88	7.7
34103	Lake Wyola	6.62	3.2	6.15	1.2
5131775	Laurel Brook	6.61	6.8	5.91	3.1
3208725	Little River		0	6.79	4.7
95092	Little Sandy Pond	6.23	1.6	6.08	2.4
3316550	Lord Brook	6.71	2.9	7.08	4.6
3524075	Mahoney Brook	5.87	2.8	5.6	0.5
8451825	Martins Pond Brook	6.79	40.1	6.98	30.25
3626475	Maynard Brook	NS	NS	5.72	1.27

8144725	McGovern Brook	7.20	15.9	7.12	9.9
2105100	Mill Brook	7.46	29.3	7.37	20.6
3419825	Mill River	7.50	54.6	7.5	37.8
7240075	Miller Brook		36	6.7	14.7
8247475	Millham Brook	6.98	22.5	NS	NS
8144825	Monoosnuc Brook	5.56	18.2	6.81	6.7
3107075	Moody Brook	6.19	8.4	6.03	4.5
3627050	Moosehorn Brook	6.41	2.7	6.46	1.9
6235775	Mulberry Meadow	5.90	6.2	6.65	7
42039	Nipmuck Pond	5.85	1	5.66	0.57
7239550	Noanet Brook		15	6.22	7.8
3314100	North River	7.02	9.5	7.49	23.7
61004	North Watuppa Lake	5.28	-0.2	NS	NS
5131350	Ohio Brook	5.11	0.4	5.33	0.88
3107575	Pond Brook	6.34	2.9	6.66	3.1
6235825	Poquanticut	5.98	4.3	6.33	3.8
7239525	Powissett Brook		10	5.93	2.5
36129	Quabbin Station 202	6.66	3.01	NS	NS
6235125	Rattlesnake Brook	4.48	-2.1	4.64	-1.8
3209275	Ripley Brook	6.09	1.8	5.59	1
3524250	Robbins Brook	5.46	-0.3	5.37	0.7
8143825	Robinson Brook	6.73	12.8	7.48	22
5334100	Rocky Run		0	7.5	74.1
5131275	Round Meadow Brook	6.26	4.3	6.16	3
3524175	Scott Brook	5.37	0.4	5.91	1.5
5133125	Scott Brook	NS	NS	NS	NS
5132600	Sewall Brook	7.17	23	NS	NS
3313850	Shingle Brook	7.78	14.3	7.87	44.9
188.0001	Shingle Island Brook	4.87	-0.5	5.35	0.8
5132750	Singletary Brook	7.21	11.2	7.28	10.4
2104200	Sleepy Hollow Brook	7.72	96	8.05	158.4
6235750	Snake River	6.18	10.2	6.1	4.8
2103725	Soda Creek	7.31	34.6	7.65	44.1
3313650	South River	7.39	39.2	7.66	34.7
3524275	Spud Brook	5.59	1.5	5.7	0.5
3313375	Stafford Brook	7.43	67.8	7.87	54.8
5132850	Stone Brook	6.48	13.1	7.19	20.5
7239925	Stop River		40	6.32	13.4
3625975	Sucker Brook	6.40	6.4	6.43	5.48
6235150	Terry Brook	4.95	-0.8	5	-0.2
3316050	Todd Brook	6.34	0.5	7	2.7
5334075	Torrey Creek	NS	NS	6.33	11.4
3524200	Towne Brook	5.08	0.8	5.62	0.2
8144250	Trapfall Brook	7.02	5.55	6.95	3.8
3314650	Underwood Brook	6.84	5.3	7.23	6.3
35090	Upper Naukeag Lake	6.04	0.9	5.51	0.3
3107700	Valley Brook	6.61	9.7	6.41	2.6

3314550	Vincent Brook	7.3	14.5	7.39	14.4
5133150	Wadsworth Brook	5.37	3.5	NS	NS
3210300	Walker Brook	6.94	9.8	6.94	10.8
4230325	Wellington Brook	6.41	25.5	6.61	19.4
3628175	West Branch Ware River	6.49	3	6.26	1.9
9558900	Weweantic River	5.62	2.1	6.01	3.6
8248425	Whitehall Brook		16	6.19	8.6
82120	Whitehall Reservoir		10.2	6.21	1.7
8145075	Whitman River	6.57	5.7	6.32	2.3
3523950	Wilder Brook	5.52	1.6	5.47	1
8144175	Willard Brook	6.91	35.3	6.85	3.45
2104100	Williams River	7.83	145.4	8	128.2
81160	Wright Pond	6.26	1.7	6.17	1.5

NS = No Sample