Evaluation of the Health of the Lower Esopus Creek

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Abstract

Water quality studies were conducted on the Lower Esopus Creek from June 2007 to October 2007. This study consisted of two components, chemical parameters and biological parameters using Benthic Macro invertebrates (BMI). For the first component, thirteen sites along the Esopus Creek were selected. Environmental parameters including; temperature, conductivity, pH and dissolved oxygen (DO) were measured at the site. Water samples were then collected and taken back to the lab for further chemical analysis. The chemical analyses preformed by titration, a DIONEX IC-3000 Ion Chromatograph and a HACH™ DR/2400 Spectrophotometer. The chemical constituents that were analyzed include: bicarbonate, total organic carbon, copper, iron, total chorine, chloride, sodium, sulfate, magnesium, calcium, fluoride, ammonia, nitrate and nitrite. The turbidity of each of the thirteen sites was also analyzed using the HACH™ 2100P Turbidimeter. The BMI samples were collected along seven riffle zone sites in accordance with NYSDEC guidelines. The BMIs were then identified to the family level. The Biological Assessment profiles for water quality using the BMIs, range from non-impacted to moderately impacted.

Introduction

The Esopus Creek is located in southeastern New York State and is a tributary of the Hudson River. It begins at Winisook Lake in the Catskill Mountain Range and joins the Hudson River in the Village of Saugerties in Ulster County New York. The Ashokan Reservoir, which is part of New York City's water supply reservoir system, divides the creek into two sections. The portion located upstream of the Ashokan Reservoir is known as the "Upper" Esopus and the reach downstream is referred to as the "Lower" Esopus.

The study reach is a section of the Lower Esopus that extends from Marbletown at the upstream end and Glenerie at the downstream end. This reach sees various types of developments on its shores ranging from agriculture, minor residential areas and city-like conditions as the river runs through the City of Kingston. Then the land use becomes more residential toward the confluence when it flows into the Hudson River. The New York State Department of Environmental Conservation (NYSDEC) has designated the waterway as Class B and B (T) within the reach studied. The classification of a stream is based off of the quality of the water and whether or not it is suitable for fish propagation and in some cases specifically trout, which is designated by (T). According to Part 861.4 of the NYSDEC guidelines the portion classified as B (T) extends "from former [tributary] 21 (Tannery Brook) in City of Kingston to [tributary] 41, which enters from north approximately 0.7 miles east of Ashokan Dam (www.dec.ny.gov)". Class B waters are best used for primary and secondary contact recreation and fishing (NYSDEC Water Quality Regulations). According to the NYSDEC, These waters shall also be suitable for fish propagation and survival.

This project focused on collection of monthly environmental data in the field, collection of water samples for chemical analysis and the biological analysis of riffle zones. This data was also compared to land use to aid in the determination of the health of the Esopus Creek. Data was collected in early June, late June, July, August, September, and October. During sample collection about 500mL to 1000mL of stream water was collected. Temperature, pH, dissolved oxygen and conductivity were measured in the field using hand probes. Chemical components were analyzed using the HACH™ DR/2400 Spectrophotometer and the DIONEX IC-3000 Ion Chromatograph. The constituents analyzed for include total chlorine, nitrate, chloride, nitrate, iron, copper, fluoride, sulfate, sodium, magnesium, calcium, ammonia and total organic carbon. Turbidity was measured using the HACH™ 2100P Turbidimeter. Land use was determined using ground proofing and a computer map generated in ArcMap 9. This map was based off of Ulster County parcel data from the Tax Assessors office. Soil information was gathered using soil survey data published for Ulster County.

The NYSDEC had conducted studies on the Lower Esopus Creek at various times in the mid 1990s. This stretch of the Esopus Creek was chosen for this study in 2007 due to the large lapse of time. It is important to attain multiple data sets over time so that trends can be discovered and any increase or decrease in the quality of the water body can be monitored. This study was done as a follow up to NYSDEC testing done at various times in the mid 1990's. It is important to attain multiple data sets over time so that trends can be discovered and any increase or decrease in the quality of the water body can be monitored. The results of this project will be used as a baseline for future studies along the Lower Esopus as well as a comparison to previous work already accomplished by the NYSDEC.

Benthic macro-invertebrates (BMIs) are often used as biological indicators to determine water quality. Benthic macroinvertebrates, also known as bottom dwellers, are animals without backbones that live on the bottom of streams and other aquatic areas. BMIs are larval insects such as dragonflies, caddisflies, stoneflies or organisms such as worms, mollusks and crustaceans. Benthic animals are the predominate food for many fish and they also regulate populations of phytoplankton and zooplankton (J.S. Levinton, and J. R. Waldman). BMIs have several characteristics that make them useful as water quality indicators. BMIs have a relatively long life cycles and limited migration patterns. This enables them to be easily studied and sampled. Since BMIs are not very mobile, they are often unable to escape from polluted areas. Benthic macro-invertebrates assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances, thus providing strong information for interpreting cumulative effects (USEPA).

Methods

The purpose of this project was to determine the water quality of the Esopus Creek through both biological and chemical studies. Thirteen sites for chemical analysis were chosen along the Esopus Creek that allowed for easy access to the creek. These sites ranged from Marbletown to Lake Katrine.

Chemical

Each site was sampled once monthly, from June to October 2007, with the exception of June which was sampled twice. See appendix for specific dates. At each site, water samples were collected and stored in High Density Poly-Ethylene (HDPE) bottles. Other environmental parameters, such as pH, temperature, dissolved oxygen (DO), and conductivity was measured on site using an YSI-550A Dissolved Oxygen meter, an OAKTON pH/Conductivity meter, and a Pulse Instrument IQ125 handheld pH meter. All samples were refrigerated upon return to the lab, and during transport were kept in a cooler. In order to preserve the cations present in the samples, 30 mL of each sample were acidified to an approximate pH of 2.0 using concentrated nitric acid.

Tests for the common cations and anions were done using a HACH™ DR/2400 Spectrophotometer and a DIONEX IC-3000 Ion Chromatograph. The HACH™ DR/2400 Spectrophotometer tested for Total Organic Carbon, copper, iron, total chlorine, and ammonia. The DIONEX IC-3000 Ion Chromatograph tested for nitrate, nitrite, fluoride, sulfate, chloride, sodium, magnesium, and calcium. The procedure for all HACH™ tests can be found in the HACH™ instruction manual. All measurements for the HACH™ tests were done using Thermo Scientific Finnpipettes and the pre-measured reagent packets provided. The DIONEX IC-3000 Ion Chromatograph was calibrated for cation and anion analysis using prepared standards. Each cation sample was run through a CSRS-2mm column and each anion sample was run through an ASRS-2mm column. Before testing, both cation and anion samples were prepared with a 0.2um Nalgene filter. This filter removed any large particles that could damage the ion chromatograph. Samples ready for analysis were placed in 10 mL DIONEX vials covered with sterile membrane caps. This helped to protect the sample from any contamination and prevent any evaporation during analysis.

Tests were also run to determine the levels of bicarbonate and turbidity. To determine bicarbonate levels, a 60 ml volume of the sample was titrated with 0.1 M HCl. When the Bromcresol green pH indicator dye turned from blue to green, the end point was reached. The volume of HCl used was noted, and calculations were done. Turbidity was determined using the HACH™ 2100P Turbidimeter. Sample water was put in a 10 mL vial and inverted 2-3 times to ensure even distribution of any suspended sediment. The outside of the vial was wiped with oil to remove any fingerprints and fill in any scratches that would possibly skew the results.

Biological

The seven sites sampled were: ESOP 01, ESOP 02, ESOP 03, ESOP 04, ESOP 06, and ESOP 07A and SAWK 01. Each of these seven sites corresponded with previous testing sites of the DEC, and was easily accessible to riffle portion of the stream. The BMI samples were collected on July 12, 2007, following the New York State DEC Quality Assurance Work Plan (Bode et. al 2002).

At the time of sampling, physical and chemical environmental data were collected. This includes, but is not limited to, the depth, velocity, temperature, dissolved oxygen (DO) levels, pH, and salinity. Physical habitat parameters were also measured.

After all the physical and chemical environmental parameters were measured, the BMIs were collected. The sampling technique utilized was the kick sampling method. Kick sampling uses a net with a mesh of 800 x 900 microns and has a width of 18 inches.

The collection net was placed approximately six inches downstream of one's feet and the kick method employed for approximately five meters along the width of the riffle zone. The debris and BMI trapped in the net was transferred into a pan and examined. A quick field inspection yielded the diversity of the ecosystem to the taxonomic level of order. The collected matter was then placed in a jar and preserved with 95% ethyl alcohol.

An analysis of water quality was conducted on August 14 and August 15, 2007 by identification and evaluation of community structure. A subsample of 100 organisms was taken from the preserved sample. A spoonful of material was scooped out of the container, and the first 100 organisms found were removed for identification under a 40x dissecting microscope. Identification was accomplished with the assistance of a taxonomic key and organisms were identified to the level of family.

Based on the families present, four metric parameters are calculated. These metrics are used to determine overall water quality of each site. The four metrics calculated were EPT family richness (F-EPT), Family Richness (FR), Family Biotic Index, Percent Model Affinity (PMA), and the Biological Assessment Profile Score (BAP). The F-EPT accounts for the total number of families that are in the orders; Ephemeroptera (mayflies) Plecoptera (stoneflies) and Trichoptera (caddisflies). These three orders are considered to be mostly clean water organisms are generally associated with good water quality. The FR is the total number of families present from all orders in the sub sample. The higher the FR value, the more likely the stream will have a better water quality evaluation. The FBI is a metric based off of the Hilsenhoff Biotic Index. This index assigns individual values to BMI based on their tolerance levels to pollutants. The values range from 0 to 10. A score of zero is intolerant to pollutants where as a score of ten is most tolerant. The PMA compares the sub sample community to a DEC model of a non-impacted community to determine the water quality in the sub sample. The DEC model community has 40% Ephemeroptera, 5% Plecoptera, 10% Trichoptera, 10% Coleoptera, 20% Chironomidae, 5% Oligocheata and 10% other. Taken together, the four values give the Biological Assessment Profile (BAP). Each of the four previous metrics was converted to a scale of 10 and then averaged together to determine the Biological Assessment Profile Score (BAP). Depending on the results, the BAP could fall within four ranges: Non Impacted (BAP 7.5-10), Slightly Impacted (BAP 5-7.5), Moderately Impacted (BAP 2.5-5), or Severely Impacted (BAP 0-2.5).

Results

Chemical

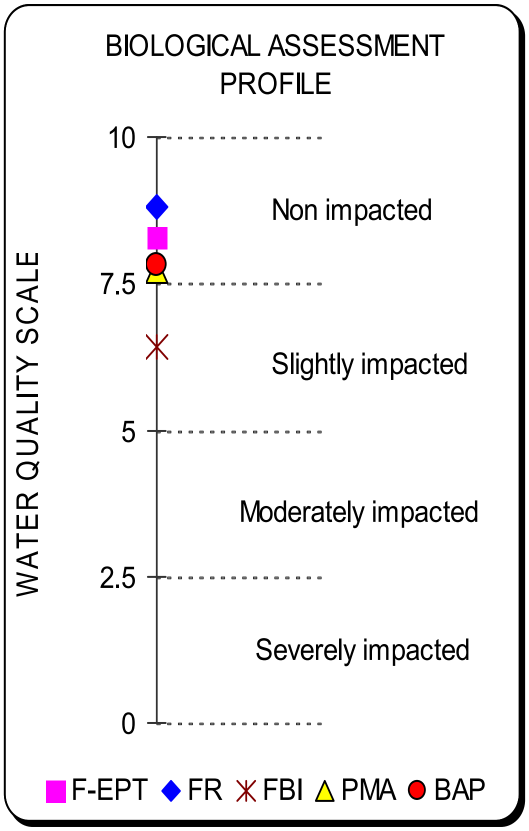
See Appendix.

Biological Results

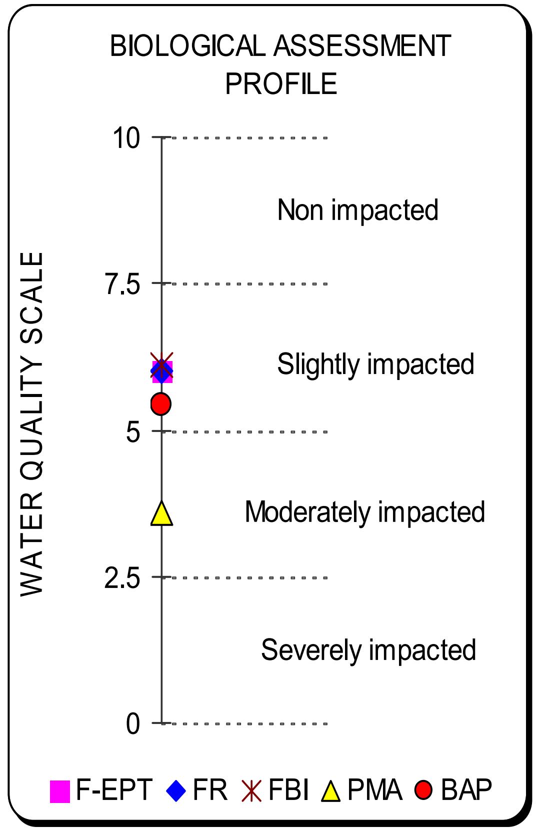
Profile 1, ESOP 01, was determined to be in the non-impacted range. The F-EPT had a value of eight families, the FR had fifteen families present, the FBI was 4.9, and the PMA was 66%. Total BAP was 7.8.

Profile 2, ESOP 02, was determined to be in the slightly impacted range. The F-EPT had a value of four families, the FR was eleven families present, the FBI was 5.1, and the PMA was 41%. Total BAP was 5.4.

Profile 1. ESOP 01



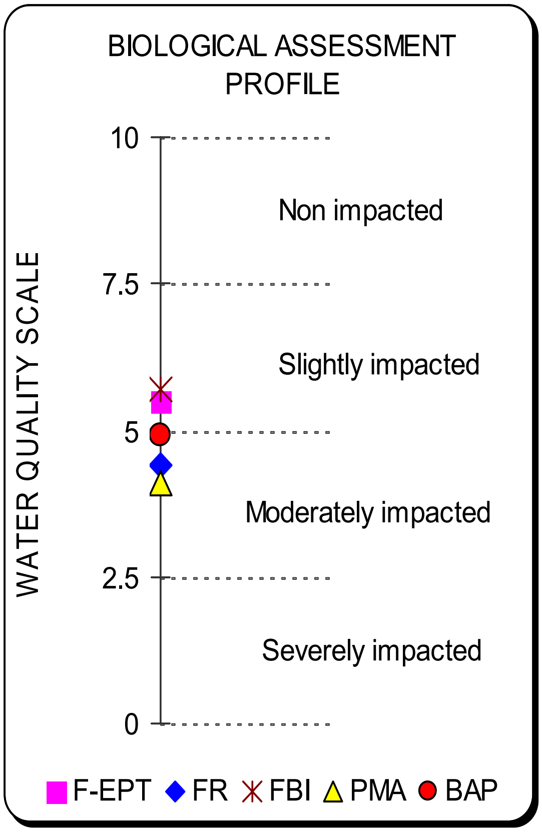
Profile 2. ESOP 02



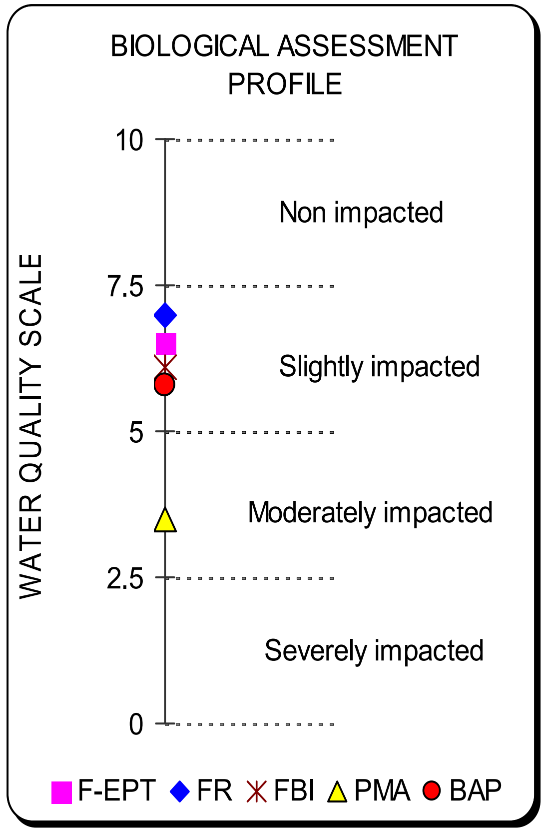
Profile 3, ESOP 03, was determined to be in the moderately impacted range. The F-EPT had three families, the FR was nine families present, the FBI was 5.5, and the PMA was 44%. Total BAP score was 4.9.

Profile 4, ESOP 04, was determined to be in the slightly impacted range. The F-EPT had a value of five families, the FR had thirteen families present, the FBI was 5.2, and the PMA was 40%. Total BAP was 5.8.

Profile 3. ESOP 03



Profile 4. ESOP 04

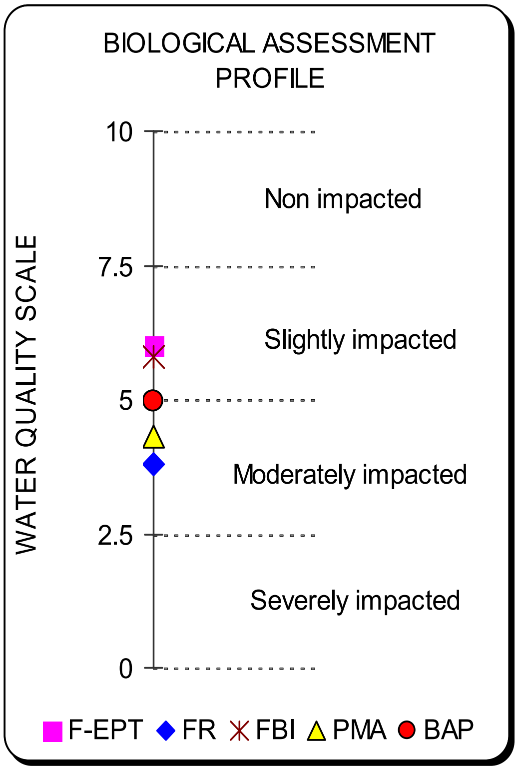


Profile 5, ESOP 06, ranged in between slightly and moderately impacted with an overall BAP score of 5.0. The F-EPT had four families, the FR had eight families present, the FBI was 5.4, and the PMA was 45%.

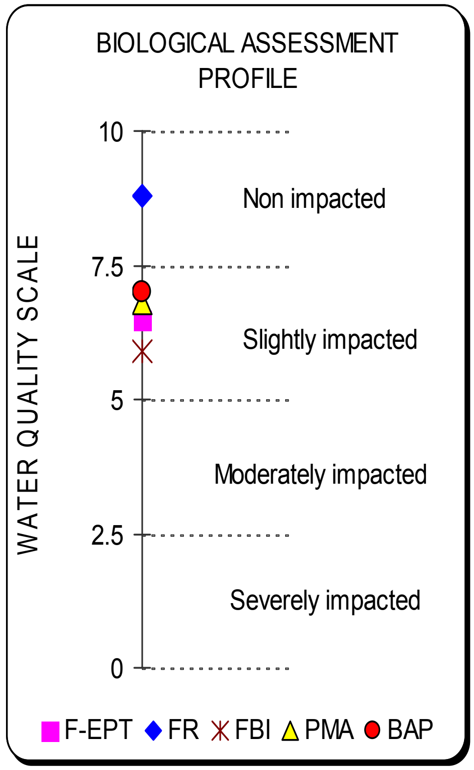
Profile 6, ESOP 07A, was determined to be in the slightly impacted range. The F-EPT had a value of five families, the FR had fifteen families present, the FBI was 5.3, and the PMA was 60%. Total BAP was 7.

Profile 7, SAWK 01, was determined to be in the slightly impacted range. The F-EPT had a value of six families, the FR had eleven families present, the FBI was 4.2, and the PMA was 45%. Total BAP was 6.3.

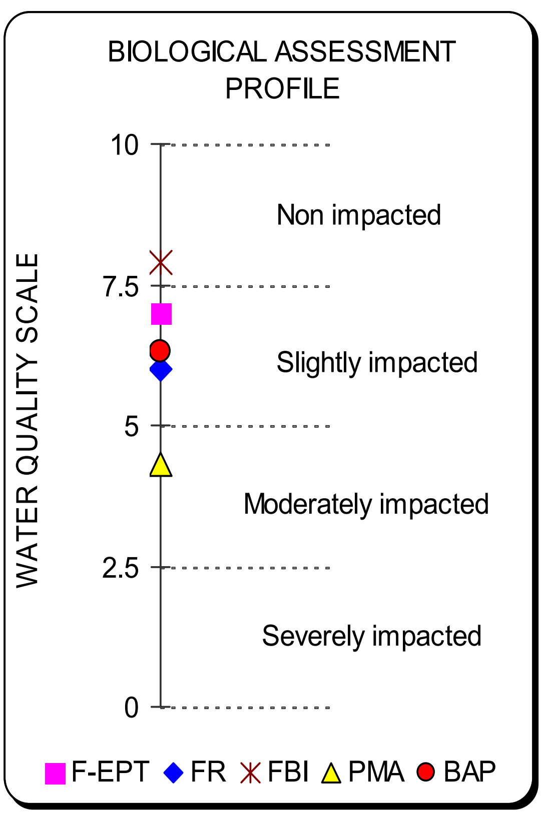
Profile 5. ESOP 06



Profile 6. ESOP 07A



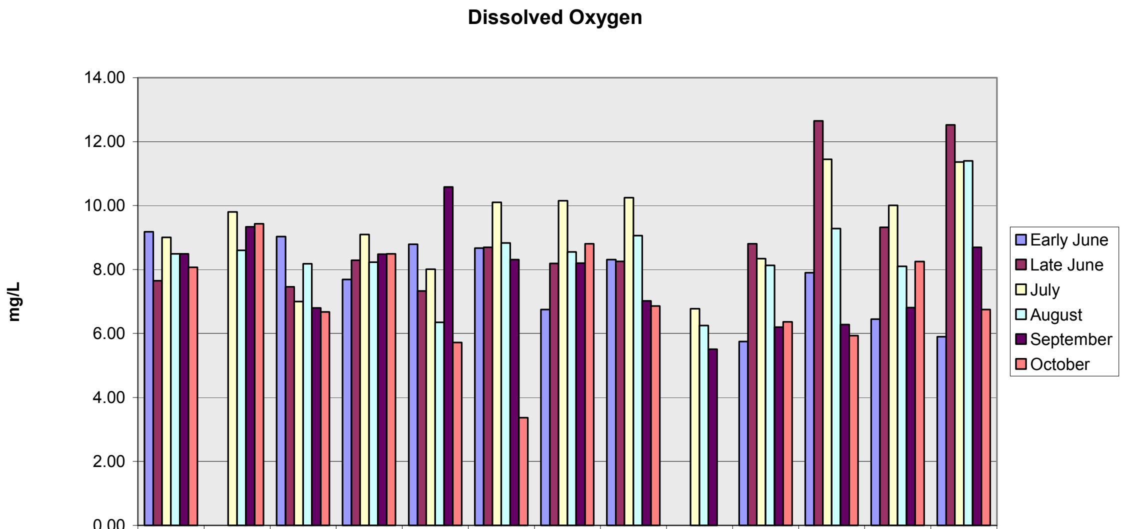
Profile7. SAWK 01



Discussion

Chemical

Dissolved Oxygen:

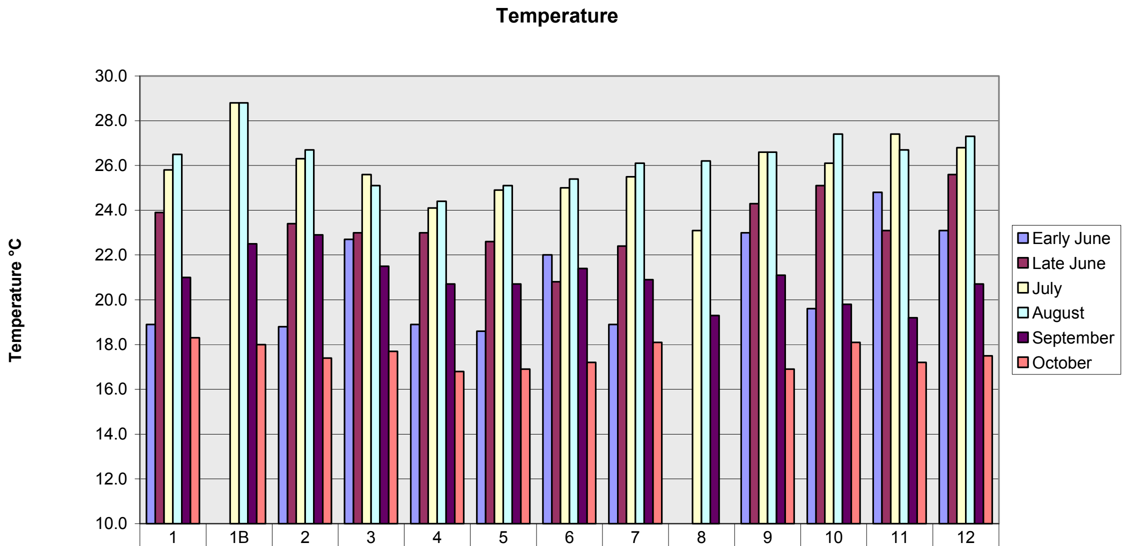


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	9.18		9.03	7.69	8.79	8.67	6.75	8.31		5.75	7.90	6.45	5.90
Late June	7.65		7.46	8.29	7.33	8.69	8.19	8.26		8.81	12.65	9.32	12.52
July	9.00	9.80	7.00	9.10	8.01	10.10	10.15	10.25	6.77	8.34	11.45	10.01	11.36
August	8.49	8.60	8.18	8.23	6.35	8.83	8.55	9.06	6.25	8.13	9.28	8.10	11.40
September	8.49	9.34	6.80	8.48	10.58	8.31	8.20	7.02	5.51	6.20	6.28	6.81	8.69
October	8.07	9.43	6.67	8.49	5.72	3.37	8.81	6.86		6.36	5.93	8.25	6.75

Site #

Dissolved oxygen (DO) is the measure of the amount of oxygen that is dissolved and available in the water column. The DEC standard for dissolved oxygen in class B streams states that at no time shall the DO concentration be less than 5.0 mg/L for trout waters and for non trout waters it shall not be less that 4.0 mg/L. The dissolved oxygen was measured in the afternoon daylights hours when the levels were generally high. The only value that fell below the DEC standard at the time of measurement was site 5 in October. Photosynthesis of benthic plants could cause the DO levels to be supersaturated during the day and plummet during the nighttime hours. High algal growths were seen during late June, July and August in sites 10, 11 and 12. Unfortunately, DO measurements were not taken during the late evening hours to make comparisons with the daytime levels.

Temperature:

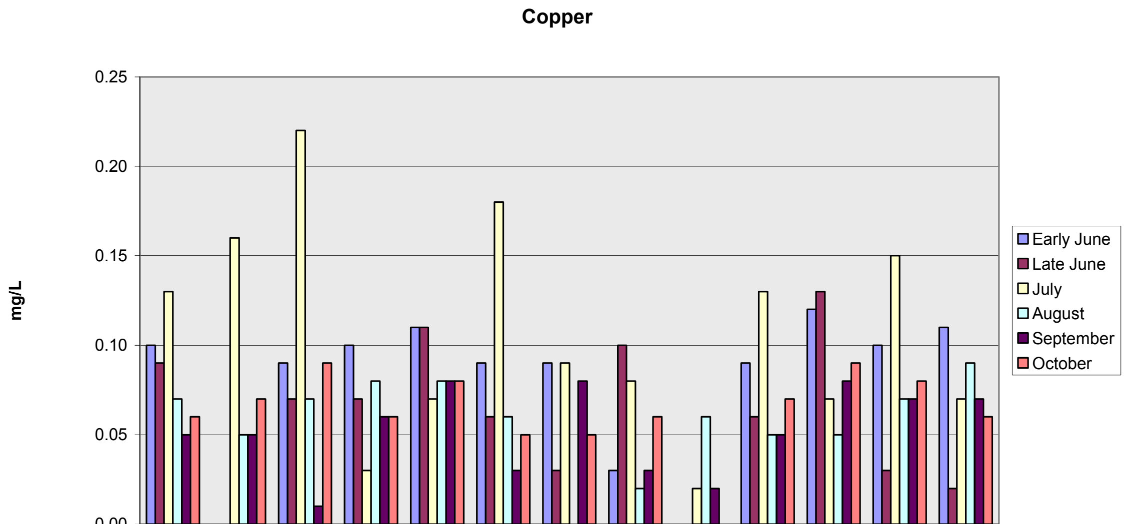


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	18.9		18.8	22.7	18.9	18.6	22.0	18.9		23.0	19.6	24.8	23.1
Late June	23.9		23.4	23.0	23.0	22.6	20.8	22.4		24.3	25.1	23.1	25.6
July	25.8	28.8	26.3	25.6	24.1	24.9	25.0	25.5	23.1	26.6	26.1	27.4	26.8
August	26.5	28.8	26.7	25.1	24.4	25.1	25.4	26.1	26.2	26.6	27.4	26.7	27.3
September	21.0	22.5	22.9	21.5	20.7	20.7	21.4	20.9	19.3	21.1	19.8	19.2	20.7
October	18.3	18.0	17.4	17.7	16.8	16.9	17.2	18.1		16.9	18.1	17.2	17.5

Site #

Temperature is an important factor for what organisms may be able to survive in a given location or the solubilities of any of the chemical constituents. In general, the temperature of the stream followed seasonal trends. August and July may also have been warmer due to low flows. Sampling was generally done in between the hours of 10 am to 4 pm where temperatures were closer to their maxima. Temperature readings were also taken near the shoreline at shallower depths; this may give higher readings than if these temperatures were taken in the center at deeper depths.

Copper:

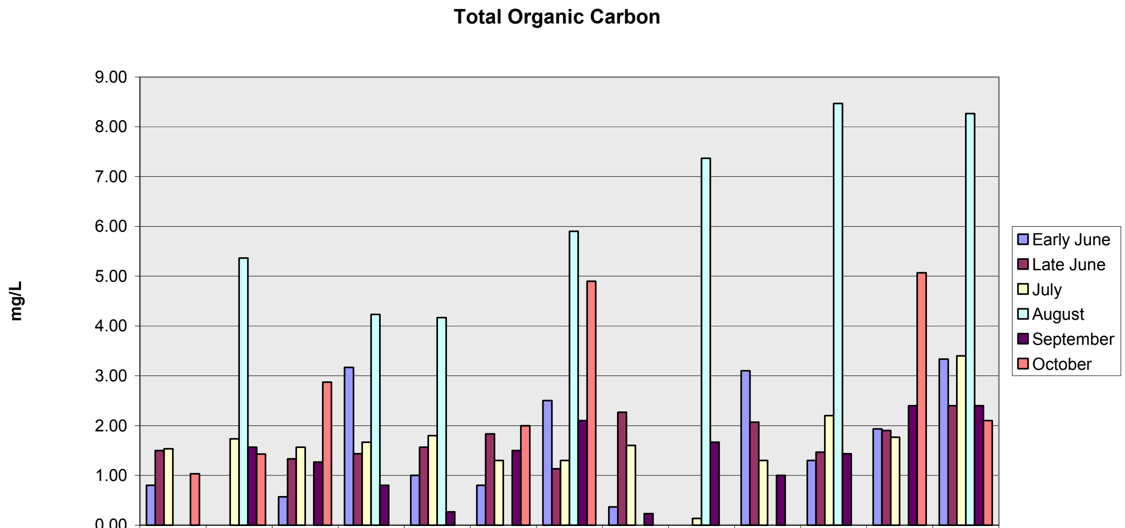


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	0.10		0.09	0.10	0.11	0.09	0.09	0.03		0.09	0.12	0.10	0.11
Late June	0.09		0.07	0.07	0.11	0.06	0.03	0.10		0.06	0.13	0.03	0.02
July	0.13	0.16	0.22	0.03	0.07	0.18	0.09	0.08	0.02	0.13	0.07	0.15	0.07
August	0.07	0.05	0.07	0.08	0.08	0.06	0.00	0.02	0.06	0.05	0.05	0.07	0.09
September	0.05	0.05	0.01	0.06	0.08	0.03	0.08	0.03	0.02	0.05	0.08	0.07	0.07
October	0.06	0.07	0.09	0.06	0.08	0.05	0.05	0.06		0.07	0.09	0.08	0.06

Site #

Some sources of copper in surface waters can arise due to runoff from road pollution, street refuse and industrial pollution. The anticipated secondary contaminant level for copper is 1 mg/L (V. Novotny and G. Chesters). All of the tested site concentrations fell below this level. There is no listed DEC standard for copper in Class B waters; however the standard for Class A waters and ground water is listed at 200 μg/L or 0.20 mg/L. In July, site 2 is slightly above at this standard level with a concentration of 0.22 mg/L.

Total Organic Carbon:

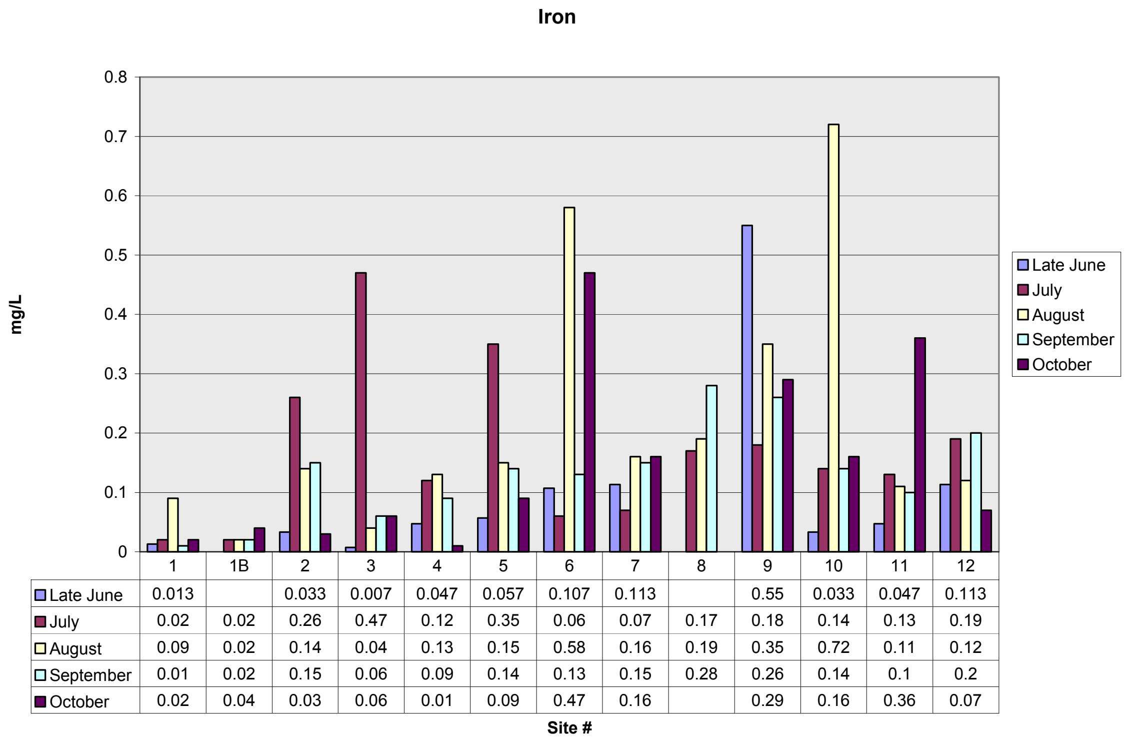


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	0.80		0.57	3.17	1.00	0.80	2.50	0.37		3.10	1.30	1.93	3.33
Late June	1.50		1.33	1.43	1.57	1.83	1.13	2.27	0.00	2.07	1.47	1.90	2.40
July	1.53	1.73	1.57	1.67	1.80	1.30	1.30	1.60	0.13	1.30	2.20	1.77	3.40
August	0.00	5.37	0.00	4.23	4.17	0.00	5.90	0.00	7.37	0.00	8.47	0.00	8.27
September		1.57	1.27	0.80	0.27	1.50	2.10	0.23	1.67	1.00	1.43	2.40	2.40
October	1.03	1.43	2.87			2.00	4.90					5.07	2.10

Site #

These values include both organic carbon from neutral sources and organic carbon for anthropogenic sources. Increased levels of total organic carbon could occur from industrial waste, water treatment and sewage treatment plants. Large increases are seen throughout the sites during the month of August. One possible explanation could be due to the increase in concentration due to low flows.

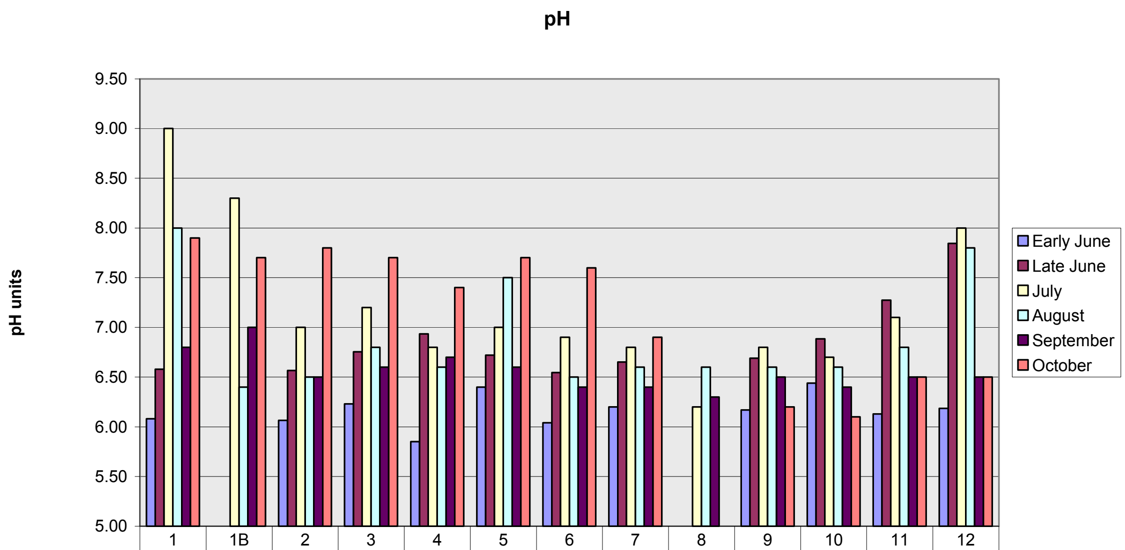
Iron:



	1	1B	2	3	4	5	6	7	8	9	10	11	12
Late June	0.013		0.033	0.007	0.047	0.057	0.107	0.113		0.55	0.033	0.047	0.113
July	0.02	0.02	0.26	0.47	0.12	0.35	0.06	0.07	0.17	0.18	0.14	0.13	0.19
August	0.09	0.02	0.14	0.04	0.13	0.15	0.58	0.16	0.19	0.35	0.72	0.11	0.12
September	0.01	0.02	0.15	0.06	0.09	0.14	0.13	0.15	0.28	0.26	0.14	0.1	0.2
October	0.02	0.04	0.03	0.06	0.01	0.09	0.47	0.16		0.29	0.16	0.36	0.07

The presence of iron can occur naturally in bedrock or can be caused by pollution from sources such as mines. Iron can also occur when iron salts coming from areas where large amounts of organic material cause reducing potentials in the subsoil water generally in conditions where the pH is low, this forms a solution of ferrous bicarbonate. When this solution reaches the open stream, carbon dioxide is lost, the pH rises and the ferrous iron is oxidized, and ferric hydroxide is deposited as a flocculent brown film (Hynes, 2001). The NYS DEC standard for Iron in class B waters is 300 µg/L or 0.30 mg/L. In late June, site 9 was above the DEC standard range with a concentration of 0.55 mg/L. Sites 3 and 5 for the July sampling dates also fall above the DEC standard with concentrations at spikes above the DEC standard range are also seen in August on sites 6, 9, and 10. During the September sampling, all sites were within range of the DEC standard. In October, spikes above the standard range were seen at sites 6 and 11.

pH:

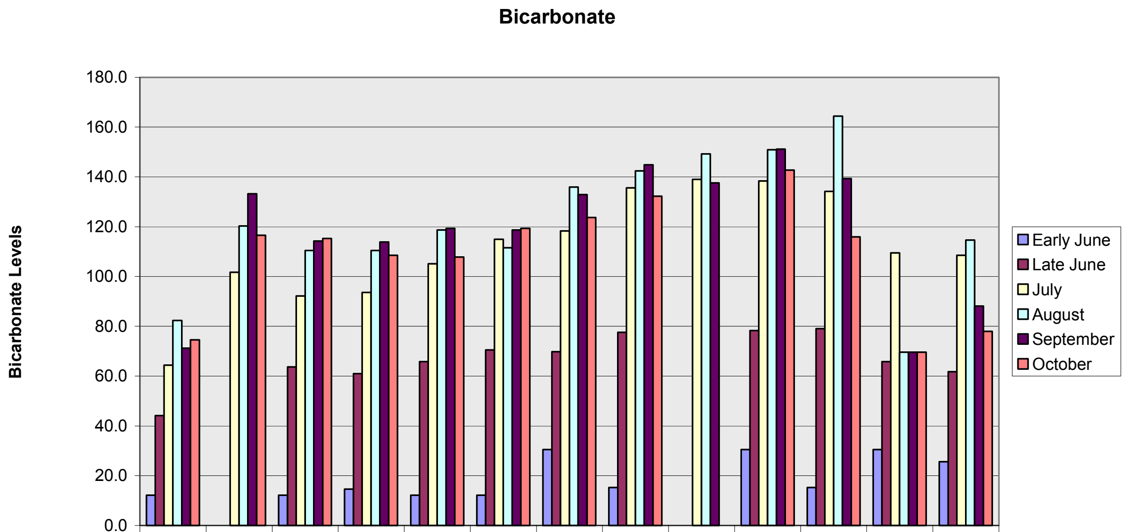


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	6.08		6.07	6.23	5.85	6.40	6.04	6.20		6.17	6.44	6.13	6.19
Late June	6.58		6.57	6.76	6.94	6.72	6.55	6.65		6.69	6.89	7.28	7.85
July	9.0	8.3	7.0	7.2	6.8	7.0	6.9	6.8	6.2	6.8	6.7	7.1	8.0
August	8.0	6.4	6.5	6.8	6.6	7.5	6.5	6.6	6.6	6.6	6.6	6.8	7.8
September	6.8	7.0	6.5	6.6	6.7	6.6	6.4	6.4	6.3	6.5	6.4	6.5	6.5
October	7.9	7.7	7.8	7.7	7.4	7.7	7.6	6.9		6.2	6.1	6.5	6.5

Site #

According to the NYS DEC Water Quality regulations, the pH shall not be less than 6.5 or more than 8.5 for class B streams. Most aquatic species prefer a pH near neutral, but can withstand a pH in the range of about 6 – 8.5 (V. Novotny and G. Chesters). During the early June, Sites 1 – 12 did not fall within the range of the DEC standards for class B streams. For late June, the pHs were within normal range. During July, Site 1 had a very high pH of 9.0. Site 8 for July had a pH of 6.2, which is just below the DEC standard. For the August sampling date the pH ranges were within the DEC standards. For the September sampling date, Site 8 and site 10 had pHs just below the standard range. For the October sampling date site 9 and 10 were below the DEC standard range for Class B streams.

Bicarbonate:



	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	12.2		12.2	14.6	12.2	12.2	30.5	15.3		30.5	15.3	30.5	25.6
Late June	44.1		63.7	61.0	65.8	70.5	69.8	77.6		78.3	79.0	65.8	61.7
July	64.4	101.7	92.2	93.6	105.1	114.9	118.3	135.6	139.0	138.3	134.2	109.5	108.5
August	82.4	120.3	110.5	110.5	118.7	111.5	135.9	142.4	149.2	150.9	164.4	69.6	114.6
September	71.2	133.2	114.2	113.9	119.3	118.7	132.9	144.8	137.6	151.2	139.3	69.6	88.1
October	74.6	116.6	115.3	108.5	107.8	119.3	123.7	132.2		142.7	115.9	69.6	78.0

Site Number

Bicarbonate can exist in the water column from a variety of sources. Bicarbonate can occur from water which has percolated through the soil which is rich in carbon dioxide and similarly rich in hydrogen ions (Hynes). This can be seen by the relationship:

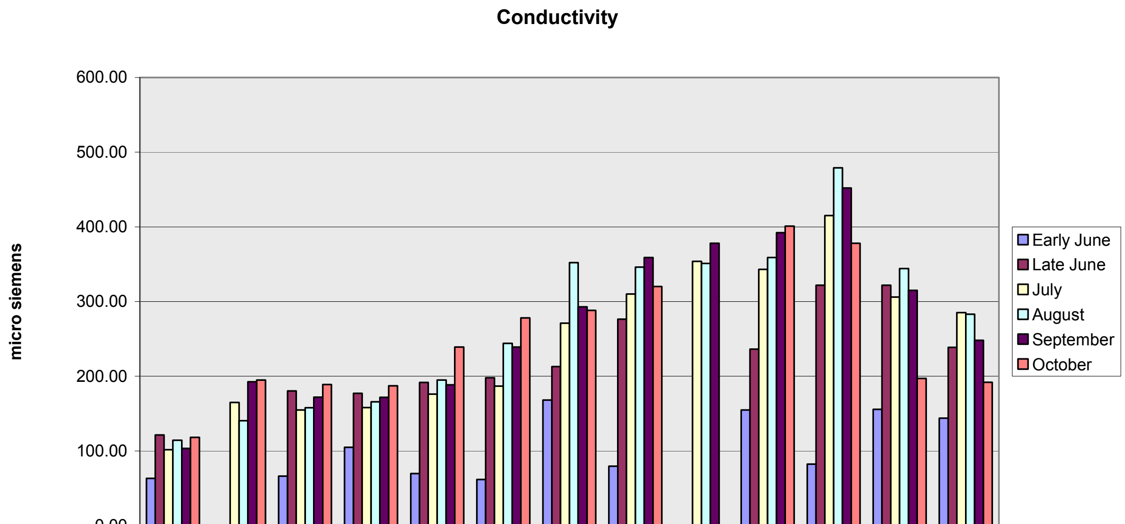
$$H_2O + CO_2 \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

Bicarbonate is also present largely due to calcium carbonate. Calcium carbonate is a common constituent of many rocks including limestone. Calcium carbonate is soluble in carbonic acid and it has the relationship:

$$CaCO_3 + H_2CO_3 \rightarrow Ca(HCO_3)_2 \rightarrow Ca^{2+} + 2HCO_3^-$$

Higher levels of bicarbonate are seen during the warmer months, this is most likely due to its increase in solubility due to warmer waters. Bicarbonate plays an important role in streams due to its buffering capacity. Bicarbonate contributes to the alkalinity in the stream and helps to stabilize the pH.

Conductivity:

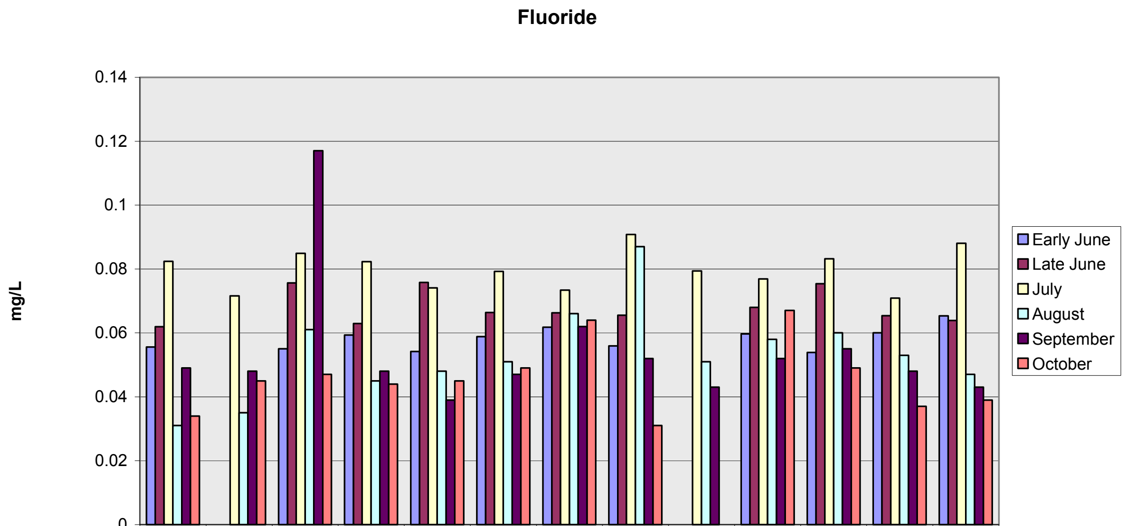


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	63.30		66.30	104.70	69.65	61.70	168.05	79.50		154.80	82.20	155.60	143.70
Late June	121.40		180.30	177.10	191.60	198.00	212.75	276.50	0.00	236.50	322.00	322.00	238.50
July	101.5	164.9	155.0	158.0	176.0	186.7	271.0	310.0	354.0	343.0	415.0	306	285.0
August	114	140	158	166	195	244	352	346	351	359	479	344	283
September	103.4	192.5	171.9	171.6	188.5	239	293	359	378	392	452	315	248
October	118.0	195.0	189.0	187.0	239.0	278	288	320		401	378	197	192

Site #

Conductivity is a measure of the total dissolved solids that are suspended in the water column. There is a significant increasing trend moving downstream from Marbletown to Lake Katrine. The highest levels of conductivity are found at the sites located in Kingston. This is due to the increased amount of impervious surfaces that are associated with more industrialized and urbanized areas. The source of the total dissolved solids that allow for the measurement of conductivity is primarily runoff consisting of road salt, and any salt substances that are used in industrial and urbanized areas. The values decrease as the sites near Lake Katrine, which is mostly a residential area, increasing the amount of porous surfaces, reducing runoff.

Fluoride:

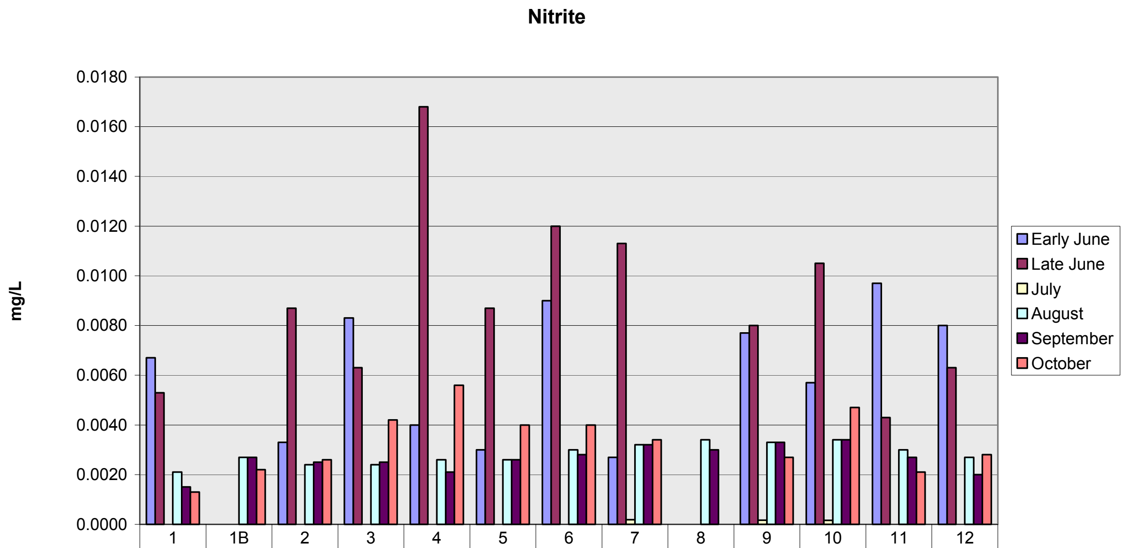


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	0.0556		0.055	0.0593	0.0542	0.0588	0.0618	0.0559		0.0597	0.0539	0.06	0.0653
Late June	0.0619		0.0756	0.0629	0.0758	0.0664	0.0663	0.0655		0.068	0.0754	0.0654	0.0639
July	0.0824	0.0716	0.0849	0.0823	0.0741	0.0792	0.0734	0.0908	0.0794	0.0769	0.0832	0.0709	0.0881
August	0.031	0.035	0.061	0.045	0.048	0.051	0.066	0.087	0.051	0.058	0.06	0.053	0.047
September	0.049	0.048	0.117	0.048	0.039	0.047	0.062	0.052	0.043	0.052	0.055	0.048	0.043
October	0.034	0.045	0.047	0.044	0.045	0.049	0.064	0.031		0.067	0.049	0.037	0.039

Site #

The standard for Fluoride as set by the DEC is 1.5 ppm for potable water. There was no standard given for Class B streams. All results are well below the drinking water standard. Fluoride can enter the groundwater through contact with fluorine containing rocks and minerals, as well as through pollutants such as refrigerants, plastics, and pesticides.

Nitrite:

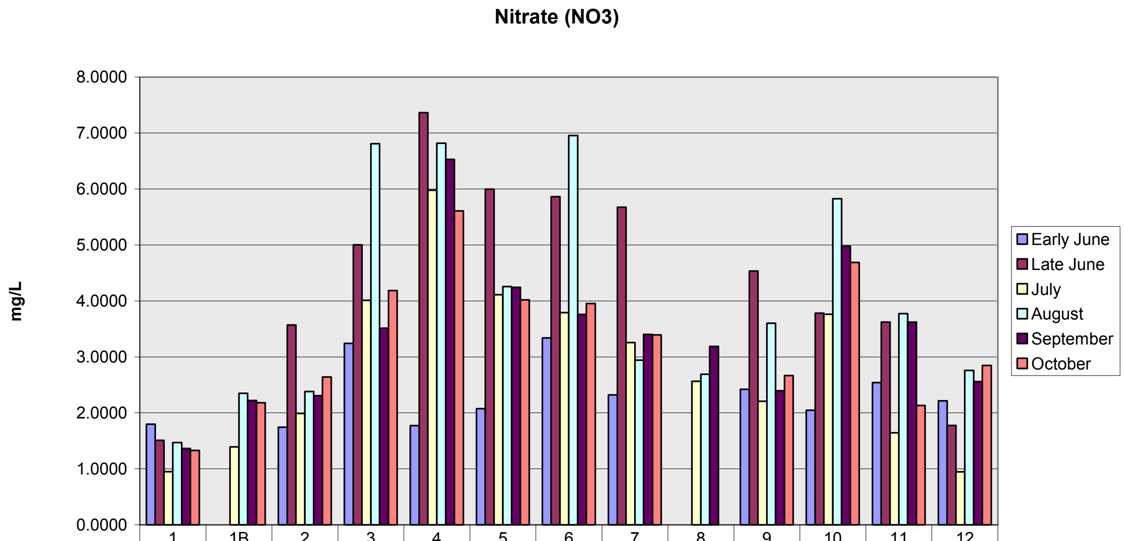


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	0.0067		0.0033	0.0083	0.0040	0.0030	0.0090	0.0027		0.0077	0.0057	0.0097	0.0080
Late June	0.0053		0.0087	0.0063	0.0168	0.0087	0.0120	0.0113		0.0080	0.0105	0.0043	0.0063
July								0.00019		0.00017	0.00016		
August	0.0021	0.0027	0.0024	0.0024	0.0026	0.0026	0.0030	0.0032	0.0034	0.0033	0.0034	0.0030	0.0027
September	0.0015	0.0027	0.0025	0.0025	0.0021	0.0026	0.0028	0.0032	0.0030	0.0033	0.0034	0.0027	0.0020
October	0.0013	0.0022	0.0026	0.0042	0.0056	0.0040	0.0040	0.0034		0.0027	0.0047	0.0021	0.0028

Site #

The standard for nitrite as set by the DEC is 0.1 mg/L for warm water fishery waters and 0.02 mg/L for cold-water fishery waters. All values are well below the standard. The values for nitrite spike at the sites within the town of Hurley. This area is primarily used for agricultural purposes. Because fertilizer is high in nitrogen based substances, the runoff that comes from the farms would be rich in nitrite.

Nitrate:

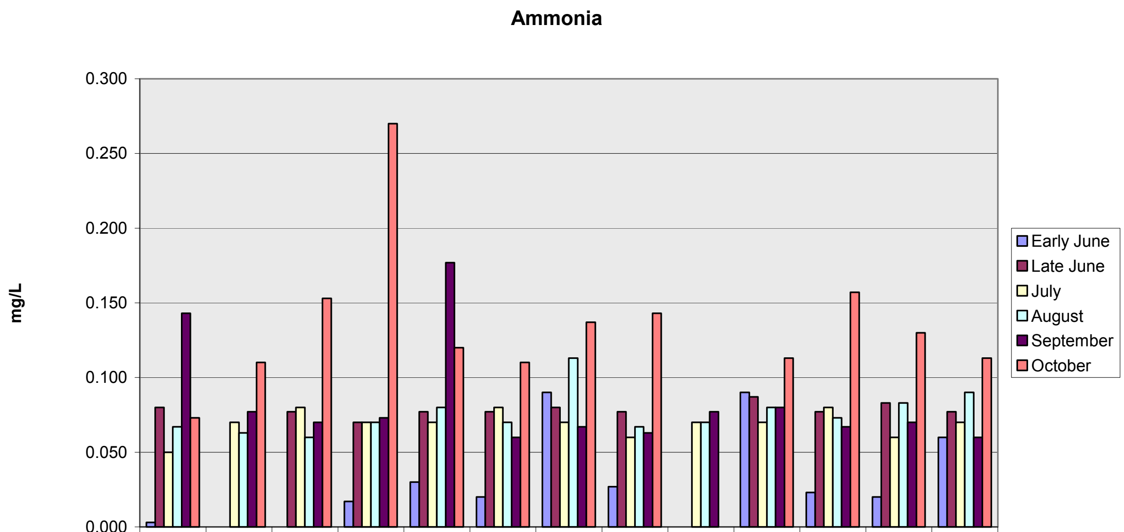


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	1.7984		1.7447	3.2401	1.7739	2.0773	3.3395	2.3217		2.4221	2.0467	2.5414	2.2182
Late June	1.5083		3.5711	5.0033	7.3648	5.9960	5.8621	5.6741		4.5339	3.7831	3.6227	1.7751
July	0.9500	1.3933	1.9906	4.0117	5.9774	4.1113	3.7895	3.2552	2.5616	2.2043	3.7606	1.6413	0.9445
August	1.468	2.349	2.383	6.809	6.82	4.257	6.957	2.941	2.691	3.6040	5.826	3.772	2.757
September	1.3650	2.22	2.3070	3.5140	6.5310	4.2420	3.7580	3.4020	3.1880	2.3980	4.9800	3.6220	2.5610
October	1.3280	2.181	2.6420	4.1840	5.6110	4.0180	3.9530	3.3930		2.6690	4.6880	2.1340	2.8480

Site #

The standard for nitrate as set by the EPA is 10 mg/L for potable water. There is no standard found for class B streams. All results are well below the standard for drinking water. The results for Nitrate are very similar to that of Nitrite. Nitrate also spikes around the agricultural areas along the Esopus Creek. This indicates that the most likely source for Nitrate is also agricultural runoff.

Ammonia:

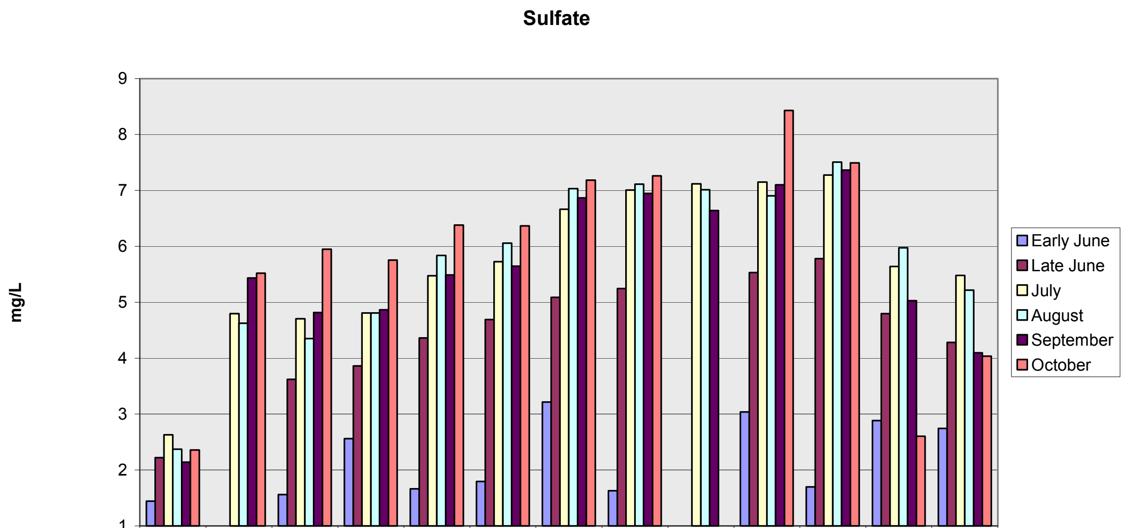


Site #	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	0.003		0.000	0.017	0.030	0.020	0.090	0.027		0.090	0.023	0.020	0.060
Late June	0.080		0.077	0.070	0.077	0.077	0.080	0.077		0.087	0.077	0.083	0.077
July	0.05	0.07	0.08	0.07	0.07	0.08	0.07	0.06	0.07	0.07	0.08	0.06	0.07
August	0.067	0.063	0.060	0.070	0.080	0.070	0.113	0.067	0.070	0.080	0.073	0.083	0.090
September	0.143	0.077	0.070	0.073	0.177	0.060	0.067	0.063	0.077	0.080	0.067	0.070	0.060
October	0.073	0.110	0.153	0.270	0.120	0.110	0.137	0.143		0.113	0.157	0.130	0.113

Site #

The standard for ammonia as set by the DEC for Class B waters varies with both pH and temperature. The lowest possible standard is for pH 6.5 from 15-30 $^{\circ}$C at 1.9 mg/L. All results are well below this level. The trends for ammonia show two spikes, one in the agricultural areas (sites 1-5) and the second in the industrial area (sites 6-12). The highest spikes occur during the October sampling date at site 3 and site 10. Possible sources for these spikes are agricultural runoff at site 3, and industrial runoff at site 10.

Sulfate:

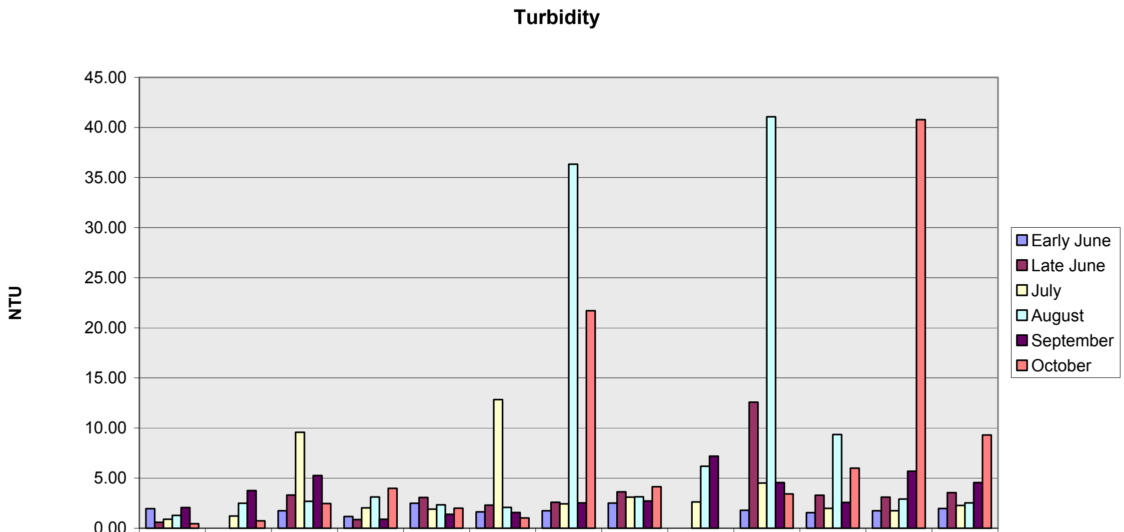


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	1.4452		1.5591	2.558	1.6626	1.7932	3.2182	1.6298		3.0394	1.695	2.8859	2.7435
Late June	2.2193		3.6194	3.8621	4.3615	4.6885	5.0884	5.2467		5.5299	5.7803	4.7989	4.2824
July	2.6277	4.7977	4.7056	4.8099	5.4713	5.7257	6.6639	7.0058	7.1201	7.1484	7.276	5.6386	5.4791
August	2.371	4.626	4.349	4.809	5.836	6.056	7.031	7.111	7.010	6.903	7.506	5.976	5.217
September	2.140	5.432	4.817	4.867	5.488	5.648	6.865	6.947	6.639	7.102	7.366	5.029	4.096
October	2.359	5.52	5.949	5.753	6.379	6.365	7.184	7.261		8.431	7.491	2.604	4.035

Site #

Sulfur is an element common to groundwater and in many minerals in the soil. As a result, sulfates are naturally occurring in groundwater. Possible natural sources for this occurrence are the oxidation of sulfur containing minerals, such as pyrite, and the oxidation of other organic materials. Sulfates can also be present due to anthropogenic activity. The plumes from industrial areas often contain oxides that react with the sulfur naturally present in the atmosphere, thus causing acid rain (Novotny, 1981). With the slight increase in the data from site 6 to site 10, it appears that the increased urbanization and industrial nature of the City of Kingston has caused an increase in levels.

Turbidity:

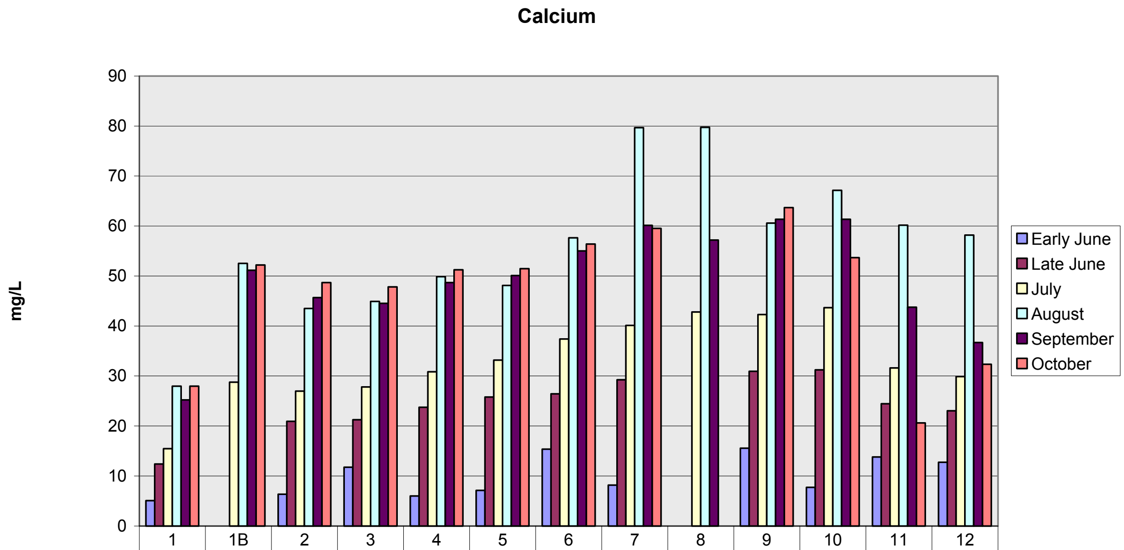


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	1.95		1.74	1.17	2.48	1.62	1.73	2.51		1.78	1.55	1.74	1.96
Late June	0.58		3.30	0.85	3.06	2.30	2.58	3.62		12.6	3.28	3.08	3.54
July	0.88	1.20	9.58	2.03	1.91	12.83	2.43	3.10	2.62	4.5	1.97	1.74	2.25
August	1.27	2.48	2.68	3.11	2.33	2.06	36.3	3.12	6.18	41.1	9.35	2.90	2.52
September	2.05	3.75	5.25	0.89	1.38	1.56	2.52	2.71	7.19	4.54	2.56	5.68	4.55
October	0.45	0.73	2.45	3.98	1.99	1.02	21.70	4.14		3.42	5.99	40.77	9.29

Site #

Turbidity is the measure of total suspended solids present in the water column. The higher the turbidity, the less light is able to penetrate the water column. This would affect the rate of photosynthesis in aquatic plants, as well as cause adverse effects on the benthic organisms living in the stream. The higher levels of iron may have contributed to the increase in values of sites 6 and 9 for the month of August. Also, on October 19, there was a rain event (see Appendix), which may have contributed to the spikes in sites 6 and 11. Upstream from site 6, the soil is primarily the Unadilla silt loam, and site 11 has Tioga fine sandy loam and a borrow pit. With increased precipitation, the soils in the borrow pit may have been disturbed and these fine grains could be carried downstream to the sampling sites.

Calcium:

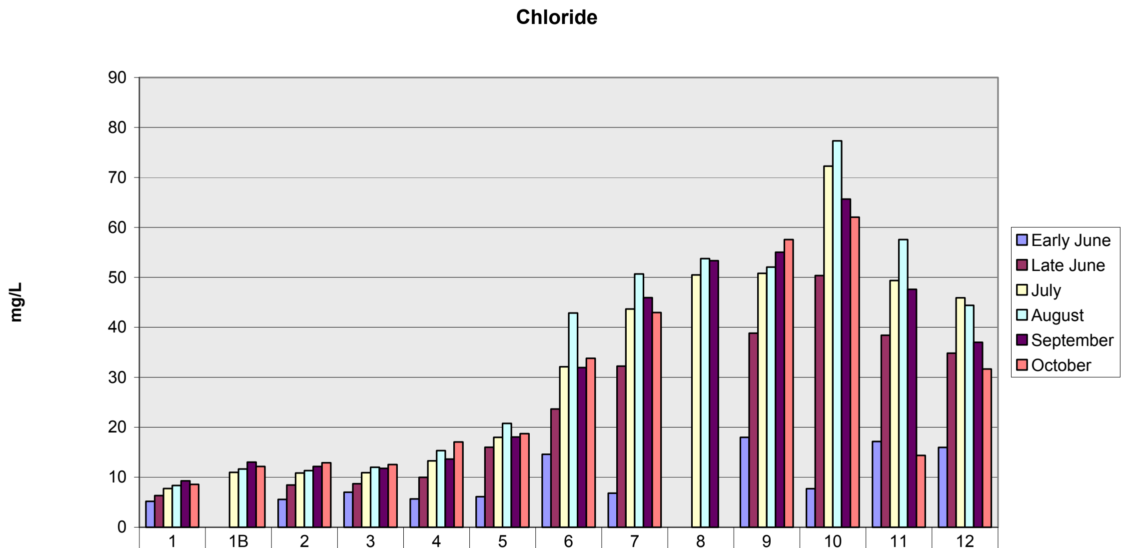


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	5.0808		6.3506	11.7482	6.0012	7.1336	15.3697	8.1554		15.5494	7.721	13.8134	12.7439
Late June	12.3977		20.9337	21.2257	23.7354	25.7821	26.4404	29.2372		30.9256	31.2418	24.4402	23.03
July	15.4594	28.763	26.9685	27.8148	30.8308	33.1836	37.3863	40.1024	42.8143	42.2858	43.6601	31.6221	29.8846
August	27.953	52.51	43.494	44.907	49.887	48.122	57.661	79.665	79.720	60.590	67.145	60.164	58.178
September	25.206	51.144	45.674	44.516	48.692	50.079	55.003	60.139	57.187	61.332	61.342	43.759	36.680
October	27.951	52.206	48.684	47.813	51.252	51.450	56.371	59.523		63.658	53.673	20.608	32.340

Site #

Calcium is a standard component of most fresh water since it is a commonly occurring element in soil and bedrock. Carbonates are very common in bedrock, and as they are weathered and dissolve, calcium is released into the soil and groundwater. Calcium is also present in road runoff (Novotny, 1981). At site 3 the stream passes by Stockbridge-Farmington gravely silt loams (SmB), which has limestone bedrock according to the Soil Survey of Ulster County, NY. The highest level of calcium was located at sites 7 and 8 in the City of Kingston area and at the golf course (site 8) in August where the totals were 79.665 mg/L and 79.720mg/L respectively. These high values for the month of August are possibly due to the low flow rate of the creek. Calcium is more soluble in the warmer waters therefore increases may be seen in the warmer months.

Chloride:

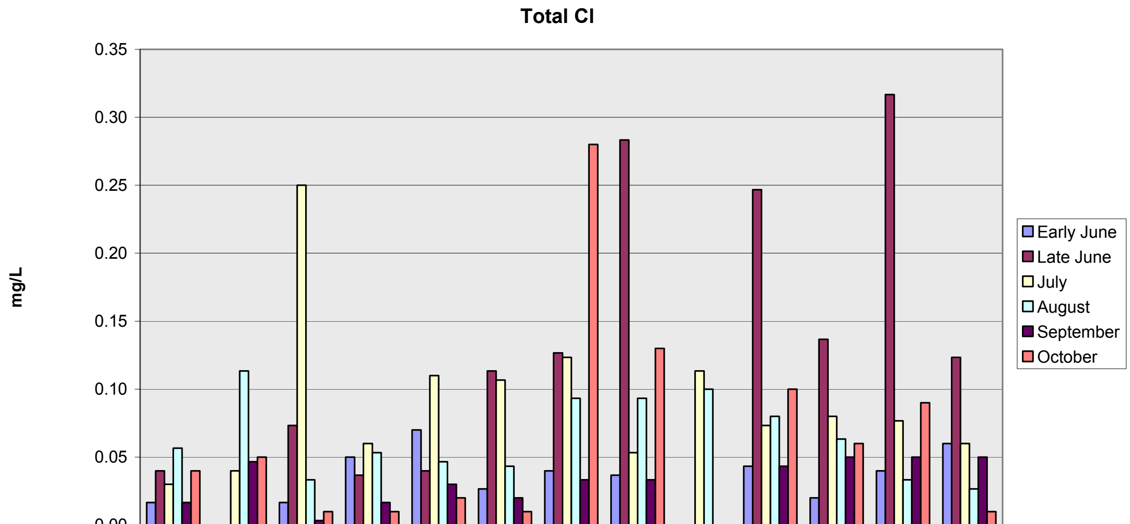


Site #	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	5.1859		5.55	7.0008	5.6461	6.1008	14.5851	6.7937		17.9941	7.7223	17.1428	15.9792
Late June	6.3259		8.4367	8.7079	9.9803	16.0209	23.6392	32.2462		38.8184	50.3606	38.4227	34.8355
July	7.7301	10.9676	10.8319	10.9121	13.2762	17.9778	32.1032	43.6539	50.4837	50.8194	72.2475	49.3591	45.9171
August	8.369	11.645	11.318	11.999	15.315	20.766	42.878	50.672	53.775	52.067	77.3	57.545	44.419
September	9.269	13.019	12.161	11.777	13.623	18.043	31.951	45.923	53.329	55.037	65.649	47.62	37.012
October	8.577	12.148	12.895	12.526	17.068	18.719	33.805	42.969		57.573	62.045	14.362	31.662

Site #

Chloride has no regulated limit in a Class B stream according to the NYSDEC Water Quality Regulations. However, the more stringent Class A regulated limit is set at 250 mg/L. The highest level measured, 77.3 mg/L at site 10 in August, falls well under the maximum contaminant level of 250 mg/L. Chloride levels can vary depending on the amount of dissolved sodium chloride or other salts such as potassium chloride. As the creek enters into the urban areas (City of Kingston), there is an increasing trend in the level of chloride present in the water. This can be attributed to the increased runoff that occurs in more urbanized areas, due to increased impervious surfaces.

Total Chlorine:

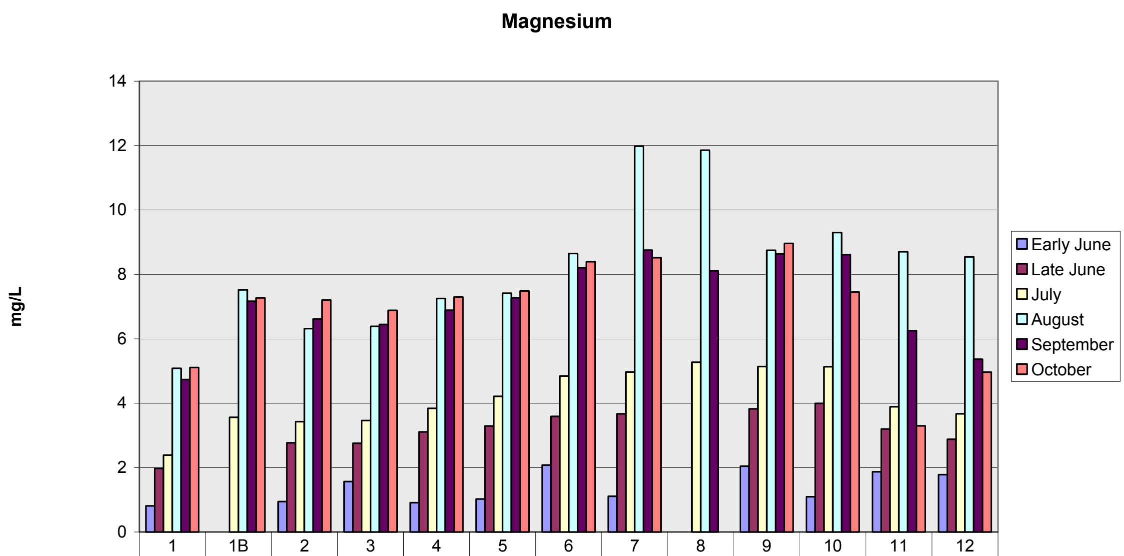


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	0.02		0.02	0.05	0.07	0.03	0.04	0.04		0.04	0.02	0.04	0.06
Late June	0.04		0.07	0.04	0.04	0.11	0.13	0.28		0.25	0.14	0.32	0.12
July	0.03	0.04	0.25	0.06	0.11	0.11	0.12	0.05	0.11	0.07	0.08	0.08	0.06
August	0.06	0.11	0.03	0.05	0.05	0.04	0.09	0.09	0.10	0.08	0.06	0.03	0.03
September	0.02	0.05	0.00	0.02	0.03	0.02	0.03	0.03	0.00	0.04	0.05	0.05	0.05
October	0.04	0.05	0.01	0.01	0.02	0.01	0.28	0.13		0.10	0.06	0.09	0.01

Site #

For total chlorine levels, the NYSDEC has a 5 µg/L limit for Class B waters. At every site, the chlorine levels are well above the set standards for almost every month. Possible sources for the levels of chlorine are road runoff and human activity. Chlorine is also used in certain compounds for farming, as well as in sewage treatment plants (Haslam, 1990). This could explain the spikes in both the agricultural as well as the urbanized areas along the creek. Just upstream of site 11, a sewage treatment plant is present, which may contribute to the chlorine content of the water.

Magnesium:

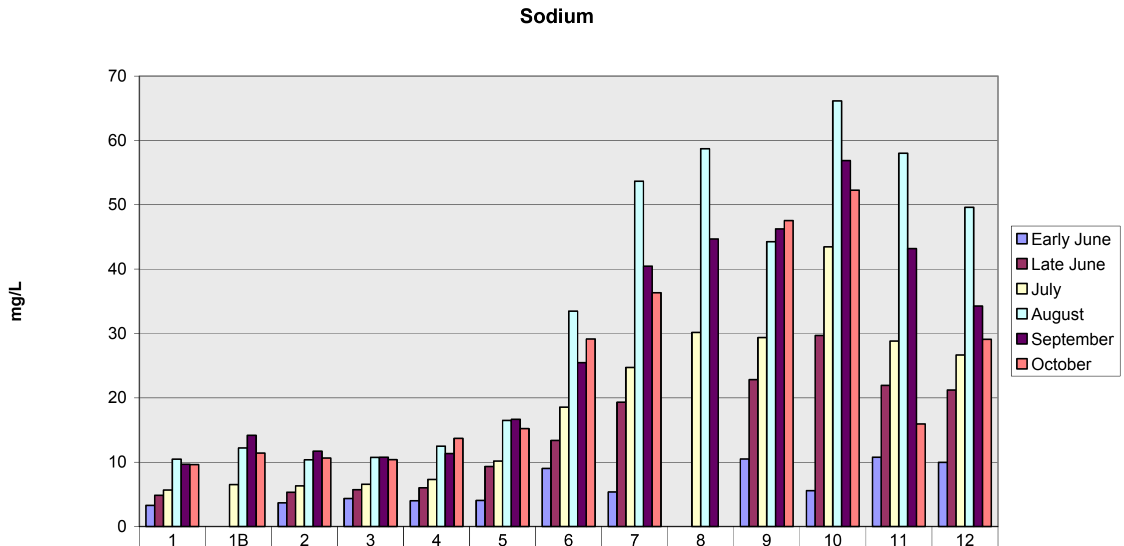


	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	0.8067		0.9457	1.5641	0.9094	1.0239	2.0743	1.1075		2.0421	1.0891	1.8671	1.7749
Late June	1.9741		2.7675	2.7517	3.1044	3.2904	3.5886	3.6697		3.822	3.9929	3.1951	2.8787
July	2.3832	3.5599	3.4226	3.4564	3.834	4.2093	4.8438	4.9705	5.2669	5.137	5.1328	3.8846	3.6700
August	5.081	7.517	6.314	6.386	7.253	7.415	8.648	11.982	11.856	8.745	9.299	8.701	8.543
September	4.734	7.166	6.612	6.447	6.887	7.272	8.202	8.75	8.108	8.635	8.613	6.25	5.364
October	5.108	7.272	7.197	6.883	7.292	7.484	8.393	8.519		8.962	7.448	3.296	4.959

Site #

The NYSDEC does not limit magnesium in surface waters designated as Class B streams. The Class A surface water limit is set at 35 mg/L. Magnesium levels all fall below the Class A surface water limit. Magnesium is a constituent of many minerals and thus is commonly found in soils and bedrock. Magnesium Oxide is also a chemical compound found in certain types of agrochemical products. There was a slight increase in the levels of magnesium for the month of August at sites 7 (11.982 mg/L) and 8 (11.856 mg/L). This is most likely due to the increase in urbanization. Magnesium trends also appear to follow temperature and have increased levels during warmer months. Calcium and magnesium levels also appear to follow the same trend.

Sodium:



	1	1B	2	3	4	5	6	7	8	9	10	11	12
Early June	3.2651		3.669	4.337	3.9993	4.0255	9.0044	5.3574		10.4896	5.5591	10.7732	9.9659
Late June	4.8348		5.3128	5.7035	5.998	9.3047	13.3639	19.3203		22.8358	29.6928	21.9291	21.2094
July	5.6682	6.4966	6.3088	6.5712	7.2962	10.1607	18.5366	24.71	30.1494	29.3515	43.4732	28.8191	26.6553
August	10.46	12.209	10.354	10.717	12.485	16.486	33.454	53.652	58.7	44.26	66.139	58.005	49.588
September	9.664	14.155	11.692	10.756	11.328	16.652	25.44	40.451	44.667	46.237	56.852	43.191	34.262
October	9.617	11.399	10.638	10.398	13.692	15.212	29.149	36.328		47.539	52.254	15.913	29.085

Site #

Sodium is found naturally in running waters from a variety of sources. It is a major constituent of many minerals, a major component of sea spray, which can be carried far inland, and appreciable amounts of sodium, can be found in rain water. The highest totals were found during the month of August. The higher concentration is most likely due to the lower flow levels during seen in August. In the later months, higher levels were also found near the City of Kingston. This may be an effect of runoff from increased urbanization.

Biological

ESOP 01

Site ESOP 01 is located off of Tongore Rd in Marbletown, NY. Algae were prevalent at this site. Ephemeroptera, Plecoptera and Trichoptera were well represented. Pteronarcyidae was present, which has a tolerance value of 0. Overall this site had a profile assessment score of 7.8 in the non-impacted category.

ESOP 02

ESOP 02 is located off of County Route 5 in Marbletown, NY. This site had an overall BAP score of 5.4 in the slightly impacted category. The lower assessment score could be due to the presence of the two impoundments upstream of the sample site. The first impoundment consisted of a stream diversion. The second impoundment, directly upstream of sampling site, was due to the streambed being utilized as a truck crossing directly. There was also a small lake, which appeared to be created by the stream diversion. Hydropsychidae and Simuliidae had the greatest abundance in the sub sample. These organisms have been found to be especially abundant below lakes (Hynes, 2001(Muller, 1954c)). The abundance of filter feeding organisms below dams may also result from the exclusion of predators ((Petts, 1984) Ward, 1976a). Both of these organisms have a tolerance value of 5. There were no stoneflies seen in the sub sample or on site.

ESOP 03

ESOP 03 was located off of Creekside Road in Hurley, NY. This site had an overall BAP score of 4.9, which just places this site in the moderately impacted category. The abundant invertebrates present here were Hydrosychidae, Chironomidae and

Empididae. These organisms have tolerance values of 5, 6, and 6, respectively. There were no stoneflies seen in the sub sample or present at the site. The lower assessment may be due to agricultural runoffs and the upstream impoundment effect.

ESOP 04

ESOP 04 is located Below the Route 29A Bridge in Hurley, NY. No stoneflies were seen at the site. This site had an overall BAP score of 5.8 and falls into the slightly impacted category. There was also an abundance of Hydropsychidae present at this site. There were forty Hydropsychidae present in the sub sample, which is the maximum number allowed by the NYSDEC. The land use was also agricultural near this site and the lower assessment may be due to runoff.

ESOP 06

ESOP 06 is located off of Van Etten Lane in Lake Katrine, NY. This site had and overall BAP score of 5.0 falling in between slightly and moderately impacted. Filamentous algae were very abundant at the time of sampling. Forty percent of the sub sample consisted of Chironomidae. The substrate present at sampling area consisted of approximately ninety-five percent bedrock. Supersaturated DO levels were present at this site. This may lead to plummeting DO levels at night limiting the survival of some organisms. Stoneflies appear to be locally extinct from ESOP 02 to ESOP 06.

ESOP 07A

ESOP 07A is located off of Rt. 9W near Glenerie, NY. This site fell into the slightly impacted category with an overall BAP score of 7.0. Stoneflies were present in the field sample but not in the sub sample. Very little algae were seen at the site. Overall, there was improved water quality.

SAWK 01

SAWK 01 is the Sawkill creek and is located near the confluence of the Esopus Creek. This site was chosen as a comparison to the Esopus Creek. This site fell into the slightly impacted category with an overall BAP score of 6.3. Chloroperlidae (stonefly) was seen in the sub sample which has a tolerance value of 0. There was a large density of organisms seen at this site. The lower assessment is most likely de to the high percentage of filter feeding caddisflies (Hydropsychidae and Philopotamidae).

Conclusion

Due to increases in population, urbanization, industry and other anthropogenic effects; regular biological stream monitoring is needed. Surface water monitoring is essential when waters are used for recreation, fishing and other human uses. Land areas hold only 2.8% of the world's total water and more than 75% of this water is locked in glacial ice or is saline (C.W. Fetter). Therefore, very little of the earth's water is available for human use. In recent years the housing and population in Ulster County and near the Esopus has increased dramatically. With an ever increasing population proper measures should be taken to protect and monitor this resource. Assessing water quality is also important to determine whether a stream meets its classification. In the Biological Assessment Profiles for the BMI studies, profiles ranged from non-impacted to falling just within the moderately impacted categories. As expected, the biological and chemical data suggest that as one moves closer to more urbanized areas the overall water quality of the stream appears to decrease. Chemical parameters such as calcium, magnesium and bicarbonate appear to be lower and of natural occurrence, whereas higher levels of constituents such as total chlorine and iron appear to be of anthropogenic nature. This may contribute to a decrease in water quality. Some sections of the stream may be limiting to fish propagation and may not meet their NYSDEC classification. Mitigation and remediation efforts might be considered to improve overall water quality.

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