A COMPARISON OF WATER QUALITY IN AN URBAN AND A WELL FORESTED STREAM: PATROON CREEK AND TENMILE CREEK, ALBANY COUNTY, NEW YORK

A Final Report of the Tibor T. Polgar Fellowship Program

by

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ABSTRACT

The rural Tenmile Creek watershed in Rensselaerville, New York, was selected as a reference stream for an ongoing water quality and restoration project on the urban Patroon Creek watershed, Albany, New York. Both watersheds drain into the Hudson River, Patroon Creek directly and Tenmile Creek after joining Catskill Creek. Monthly water samples from both creeks were analyzed for dissolved ions using an ion chromatograph. Macroinvertebrate samples were taken using a kick sampling method in July and August on Tenmile Creek, and August on Patroon Creek. These invertebrate data were compared to previous samples taken by the New York Department of Environmental Conservation (DEC) on both creeks. The null hypothesis is that water quality, measured using dissolved ions and macroinvertebrates, does not vary along Tenmile Creek; the alternative hypothesis is that measured variables fluctuate. downstream of impoundments and the Hamlet of Rensselaerville.

Preliminary results indicate that the two watersheds are very different systems, with most differences in measured variables attributable to differing land use. Mean ion concentrations for sodium, chloride were approximately 10 and 20 times larger, respectively, in Patroon Creek than in Tenmile Creek. Biotic indicators rank Patroon Creek as having poor water quality and Tenmile Creek as nearly pristine. Even with its well forested riparian buffer, it appears that the 44 ha impoundment (Lake Myosotis) and the Hamlet of Rensselaerville affect the water quality of Tenmile Creek, increasing sodium, chloride, magnesium, and calcium ion concentrations significantly. However, future monitoring will be needed to determine if these findings hold over more than a single sampling season.

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INTRODUCTION

Land-use change is occurring at an accelerated rate worldwide and constitutes one of the major threats to ecological processes. Research and monitoring at the watershed level is a useful and logical approach for gauging the impacts of land use on ecosystems. Watershed studies integrate terrestrial and aquatic systems, and large watersheds can be broken down into subunits of smaller watersheds that serve as indicators of cumulative impacts (Hunsaker and Levine 1995). Shifts in land use within watersheds negatively impact water quality in streams (Jones et al. 2001, Hunsaker and Levine 1995, Likens and Bormann 1995), and land use changes in close proximity to streams may have a larger impact on water quality than broader scale land uses (Omernik et al.1981, Lowrance et al. 1984).

The relationship between water quality and riparian vegetation has been studied throughout North America (Clausen et al. 2000, Correll 2000, Gilliam 1994, May and Horner 2000, Spruill 2000). Riparian and wetland buffers sequester sediment and potential pollutants, stabilize stream banks, and moderate stream temperature. Riparian zones also provide important wildlife habitat and corridors, and contribute to more diverse aquatic and terrestrial communities. As more and more watersheds are converted from forested or farmed land to suburban and urban land the area of impervious surfaces increases. Larger areas of impervious surfaces increase nonpoint source inputs, such as pesticides from agricultural land, fertilizers from suburban lawns, and salt from urban streets, that find their way into aquatic systems via runoff where they degrade water quality (Limburg and Schmidt 1990, Hayes and Petrusso 1998, Paul and Meyer 2001).

In the Hudson River Estuary, most of the point sources of pollution have been rectified on the main stem, but tributaries continue to add contaminants to the river. Land-use in the Hudson drainage has shifted in many areas from a largely agricultural landscape to a post-agricultural, sprawling suburban and urban landscape. The amount of land area constituting impervious surfaces, such as roads, parking lots, and buildings in suburban watersheds causes increased energy pulses, surface runoff, and erosion rates after storm events (Howarth et al. 1996). Urban streams typically have even higher percentages of impervious surfaces and lower percentages of riparian and wetland buffers, and exhibit more degraded water quality and poorer fish habitat than suburban streams (Limburg and Schmidt 1990, May and Horner 2000).

While researchers have studied inputs into the Hudson from tributaries that drain sprawling suburban and post-agricultural landscapes, inputs from urban tributaries have not been studied in detail (Findlay 2003). A partnership, including the City of Albany, W. Haywood Burns Environmental Center, University at Albany, and United States Geological Survey (USGS), among others, has undertaken the task of monitoring, the urban Patroon Creek Watershed as part of an Environmental Protection Agency Environmental Monitoring for Public Access and Community Tracking (EMPACT) grant. Patroon Creek is approximately 10 km long and flows east from the Albany Pine Bush Preserve through the City of Albany, Albany County, New York to the Hudson River. The creek drains an almost entirely urban landscape.

Reference streams are often used when trying to assess the impacts of urbanization on a stream system. An ideal reference site should entail relatively large and intact riparian zones without significant anthropogenic disturbance and share reasonable geologic and geographic commonality with the urban system (Beschta and Kauffman 2000). Monitoring a reference creek will provide a benchmark for hydrologic processes and species composition on Patroon Creek, with which researchers can compare a relatively pristine watershed to the severely degraded urban watershed. Beschta and Kauffman (2000) describe selecting a reference site as a critical task in ecological stream restoration.

The purpose of this study was to provide baseline water quality data from a reference stream, Tenmile Creek, Hamlet of Rensselaerville, Albany County, New York, for comparison with existing and ongoing water quality assessment of Patroon Creek. Water quality within Tenmile Creek was also analyzed to determine if any variation occurred along the course of the creek, with particular attention paid to water quality above and below two impoundments located on the creek and above and below the Hamlet of Rensselaerville.

METHODS

Study Areas

Patroon Creek, Albany County, New York draws its source from groundwater moving through the sands of the Albany Pine Bush Preserve and flows east through the Town of Guilderland, Town of Colonie, and City of Albany for approximately 10 km before meeting the Hudson River. The creek drains a heavily urbanized, industrial watershed and is listed as one of the most severely impacted streams in New York State (Bode at al. 1995). Two impoundments constructed in the 1800's created Rensselaer Lake, at the headwaters of the creek, and Patroon Reservoir, less than 1 km east of

Central Avenue along Interstate 90. Sediments in Patroon Reservoir are documented to contain levels of mercury (Hg), cadmium (Cd), lead (Pb), and uranium (U) higher than background levels (Arnason and Fletcher 2003). Patroon Creek drains a 37 km^2 watershed and undergoes an elevation change of 240 to 10 ft over 10 km. Researchers in the Departments of Biology and Earth and Atmospheric Sciences are currently involved in an effort to monitor water quality and explore the restoration potential of Patroon Creek.

Tenmile Creek, Albany County, New York begins as surface flow in the Partridge Run Wildlife Management Area and flows south through the Edmund Niles Huyck Biological Research Station and Preserve in the Town of Rensselaerville. The creek is set in a steep, hanging valley and drains a predominately well-forested and post-agricultural watershed with no current industrial or urban inputs. Near the Town of Oak Hill, Tenmile Creek joins Catskill Creek, which flows into the Hudson River. For this study, an approximately 10 km stretch of creek, from Partridge Run to the southern border of the Huyck Preserve was selected. This stretch of creek flows through the Hamlet of Rensselaerville and includes two impoundments, forming 4 ha Lincoln Pond and 44 ha Lake Myosotis, the drinking water supply for the hamlet. In the study area, Tenmile Creek undergoes an elevation drop from 560 m to 360 m over 10 km.

Tenmile Creek was selected as a reference site for interpreting water quality status and restoration potential on Patroon Creek for several reasons. Located within the Hudson River drainage, the streams are in close geographic proximity. Both streams contain two impoundments, both have continuous flow, and both flow through several wetland zones. The steep hanging valley of Ten Mile Creek creates a restricted drainage and comparable peak flow situations to an urban catchment. On the other hand, the well-forested E. N. Huyck Preserve provides a contrast to the severely degraded Patroon Creek watershed. Except for the Hamlet of Rensselaerville, the immediate vicinity surrounding Ten Mile Creek contains low population and road density, and consists of a primarily post agricultural/rural landscape (Wyman 1988). Although Ten Mile Creek is at a higher elevation and in a colder climate zone than Patroon Creek, finding a relatively pristine nearby creek with no urban inputs at a low elevation was not possible.

Water Sampling

From May through August 2003, water samples were collected the first Wednesday of every month from the twelve sampling sites along Patroon Creek and the ten sampling sites along Tenmile Creek. Twelve existing sample locations on Patroon Creek were used as a model for site selection on Tenmile Creek, with special consideration to include sampling above and below the two impoundments and above and below the Hamlet of Rensselaerville. Sample locations on Patroon Creek and Tenmile Creek were selected to best capture any variation in water quality over the course of the study area. Accessibility and safety were also considerations in sample site selection.

At each location, dissolved oxygen and temperature were measured in the field. A 100 ml water sample was collected in the field for analysis in the laboratory. In the laboratory, samples were filtered with a 0.45 μm filter to remove suspended sediments and pH was measured. Once the samples were filtered they were analyzed for anion and cation concentrations using a Dionex PeakNet ion chromatograph system and Chromeleon software. The specified anions and cations were fluoride (F^-), chloride (Cl^-), nitrate (NO_3^-), sulfate (SO_4^{-2}), phosphate (PO_4^{-3}), sodium (Na^+), ammonium (NH^{+1}), calcium (Ca^{+2}), and magnesium (Mg^{+2}).

Invertebrate Sampling

On July 2, 2003 and August 7, 2003, I sampled Tenmile Creek for stream macroinvertebrates at five of the ten water sample sites. The sampling protocol was that used by the Stream Biomonitoring Unit of the New York State Department of Environmental Conservation (DEC) (Bode at al. 2002). Sample locations were selected for similar depth, flow, and shade characteristics. Two sites were chosen because of their use as previous DEC monitoring sites (Abele et al. 1998). At each site I selected a 5 meter stretch of riffle habitat with a substrate of rock, rubble, gravel, or sand. The riffle was sampled for 5 minutes using a dip net (23 cm x 46 cm, mesh 0.8mm x 0.9mm). The sample was filtered with a U.S. no. 30 sieve, transferred to quart jars and preserved in 95% ethyl alcohol. Once in the laboratory, the sample was filtered again with a no. 60 sieve, and a randomly selected subsample of 100 individuals was identified to order and family. The data from orders and families were used to calculate two water quality indices: EPT (the number of families representing the three orders Ephemeroptera, Plecoptera, Tricoptera) and percent model affinity (comparing sample community structure to a model based on a pristine watershed; Bode et al. 2002). On August 5, 2003, I sampled two locations on Patroon Creek following the same protocol. These two sites were selected because of their use as previous DEC monitoring sites. Data from previous sampling on Tenmile Creek (Abele et al. 1998) and Patroon Creek (Bode et al. 1995) were used for comparison.

Statistical Analysis

Tenmile Creek sample sites were polled into three sections based on preliminary analysis: Section 1 – sample sites above Lake Myosotis; Section 2 – sample sites below Lake Myosotis, but above the Hamlet of Rensselaerville; and Section 3 – sample sites below the Hamlet of Rensselaerville. Ion concentration data were analyzed using single-factor ANOVA with site as a factor (three levels) and post hoc Bonferroni tests for pairwise comparison. All statistical analyses were performed with Systat 9.0 software. Whisker/box plot graphs were used to graphically compare selected mean ion concentrations between Patroon and Tenmile Creeks. Correlations among ion concentration data within Tenmile Creek were examined using principal components factor analysis (PCA). Cluster analysis was used to test for spatial variability in invertebrate community among the five sampling sites on Tenmile Creek. Two different indices were used to construct similarity matrices. To compare species composition, I used the Jacard Index,

$$(C_J = j / (a+b-j),$$

where j = number of species found in both sites; a = number of species found in site A; b = number of species found in site B. To compare relative abundances among taxa, I used the Sørenson Quantitative Index,

$$(C_N = 2jN / (aN+bN),$$

where aN = total number of individuals in site A; bN = total number of individuals in site B; jN = the sum of the lower of the two abundances recorded for species found in both areas (Magurran 1988). The two similarity matrices were used in Cluster Analysis to produce additive trees for a portrait of variation in the invertebrate biota among sites.

RESULTS

Water Sampling

Patroon Creek exhibited higher levels of dissolved ions than Tenmile Creek for all tested ions. The most notable differences between the two creeks were in concentrations of sodium and chloride ions (Figure 1). Mean sodium ion concentration was approximately 10 times greater and mean chloride ion concentration was approximately 19 times greater in Patroon Creek than in Tenmile Creek over the four months sampled. Magnesium and calcium ions showed only slightly less dramatic differences (Figure 1).

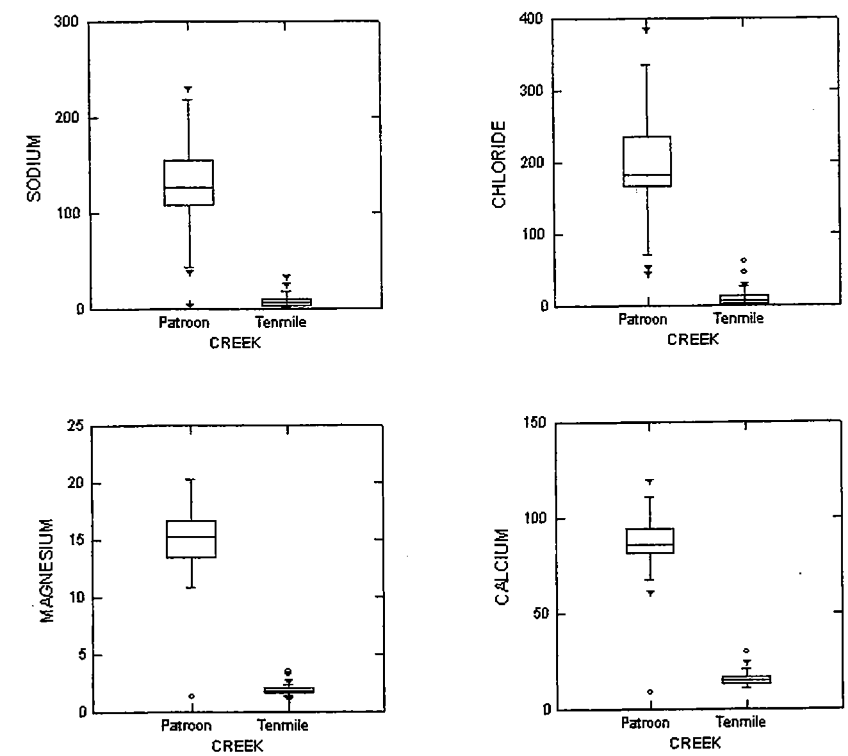

Figure 1 – Box plot comparisons of sodium, chloride, magnesium, and calcium ion concentrations (mg/l) in Patroon and Tenmile Creeks, Albany County, NY from May-September 2003. Boxes represent the range of the central 50% of values; central horizontal line marks the median; whiskers represent the total range of values; * = outliers; o = far outliers.

Nitrate and ammonium levels were low in Tenmile Creek across all sample sites (means 0.8478 and 0.2905 mg/l, respectively), and never exceeded 5 mg/l in Patroon Creek (Figure 2). Mean sulfate ion levels in both creeks (Patroon Creek - 38.45 mg/l and Tenmile Creek - 5.40 mg/l) exceeded nitrate and ammonium concentrations (Figure 2). Concentrations of phosphate fell below detectable limits for both creeks.

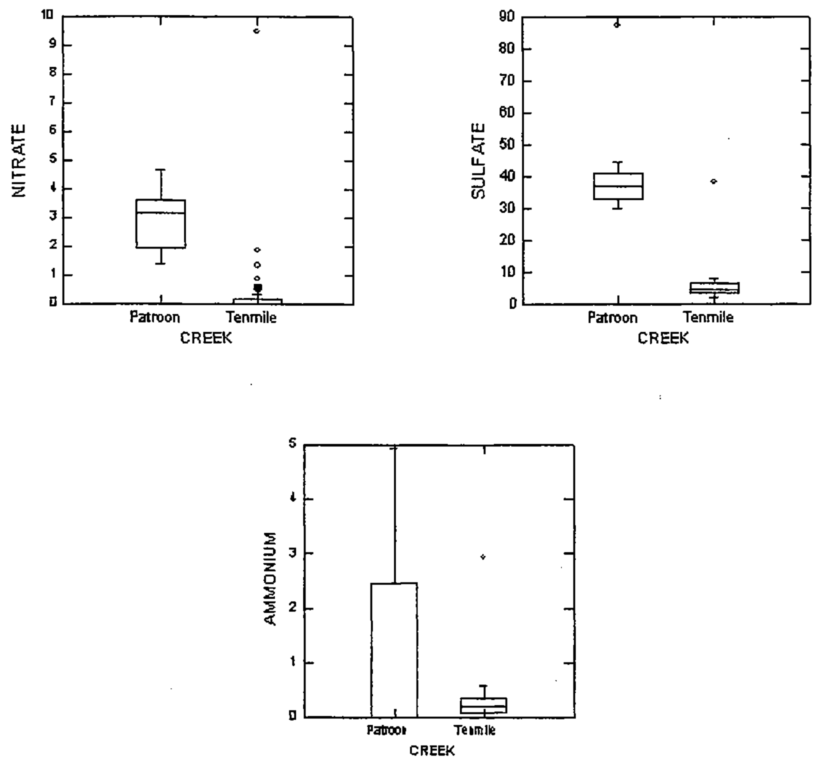

Figure 2 – Box plot comparisons of nitrate, sulfate, and ammonium ion concentrations (mg/l) in Patroon and Tenmile Creeks, Albany County, NY from May-September 2003.

Within Tenmile Creek, selected ion concentrations exhibited clear trends when separated over the three spatial groupings. Magnesium and calcium concentrations significantly increased after the Hamlet of Rensselaerville (Mg – $F_{2,37} = 4.78$ $p = 0.014$; Ca – $F_{2,37} = 7.01$ $p = 0.003$). Sodium and chloride concentrations showed a significant increase below Lake Myosotis and another significant increase below the hamlet (Na – $F_{2,37} = 56.73$ $p = 0.00$; Cl – $F_{2,37} = 36.86$ $p = 0.00$; Figure 3). Nitrate, sulfate, and

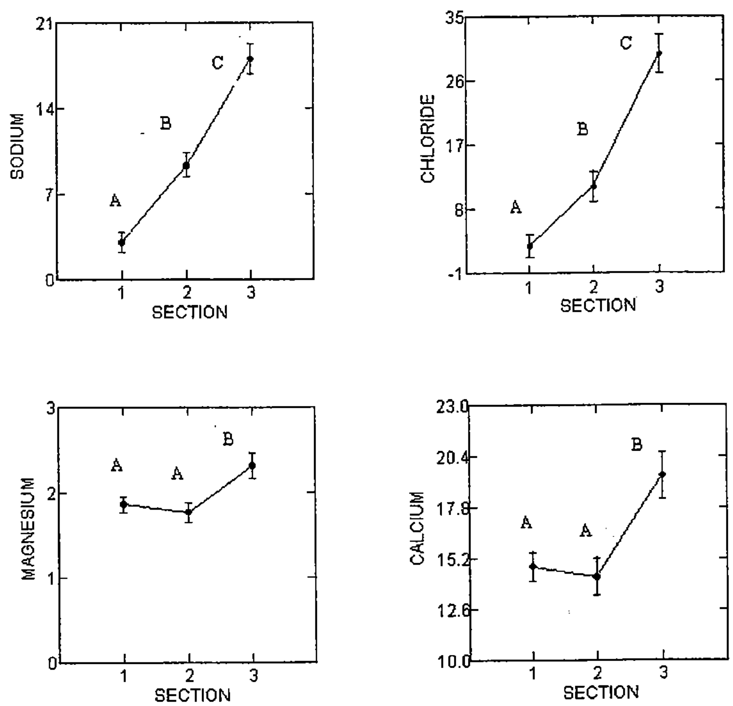

Figure 3 – Means of sodium, chloride, magnesium, and calcium ion concentrations (mg/l) along Tenmile Creek, Albany County, NY for the months of May-September 2003. Section 1 pools sample sites above Lake Myosotis; Section 2 pools sample sites below Lake Myosotis but above the Hamlet of Rensselaerville; Section 3 pools sites below the Hamlet of Rensselaerville. Different letter indicate significant pairwise difference.

ammonium displayed a graphic increase after Lake Myosotis, but showed no significant statistical difference ($p > 0.05$) between the three groupings (Figure 4). Using a PCA, nitrate, sulfate, and ammonium showed strong correlation and clustering from another strongly correlated group of ions, magnesium, calcium, sodium, and chloride (Figure 5).

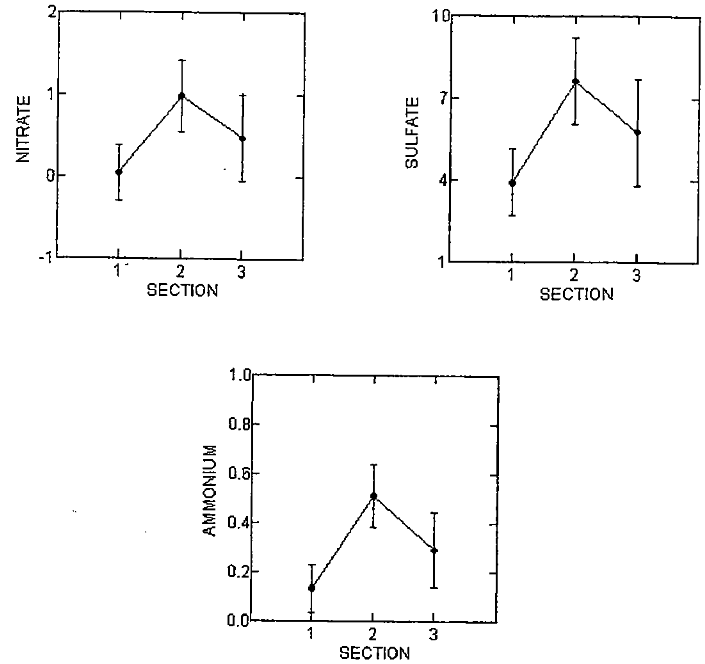

Figure 4 – Means of nitrate, sulfate, and ammonium ion concentration (mg/l) in Tenmile Creek, Albany County, NY for the months of May-September 2003. Section 1 pools sample sites above Lake Myosotis; Section 2 pools sample sites below Lake Myosotis but above the Hamlet of Rensselaerville; Section 3 pools sites below the Hamlet of Rensselaerville. Mean differences were not significant (nitrate $F_{2,37} = 1.48$, $p = 0.24$; sulfate $F_{2,37} = 1.72$, $p = 0.19$; ammonium $F_{2,37} = 2.84$, $p = 0.07$).

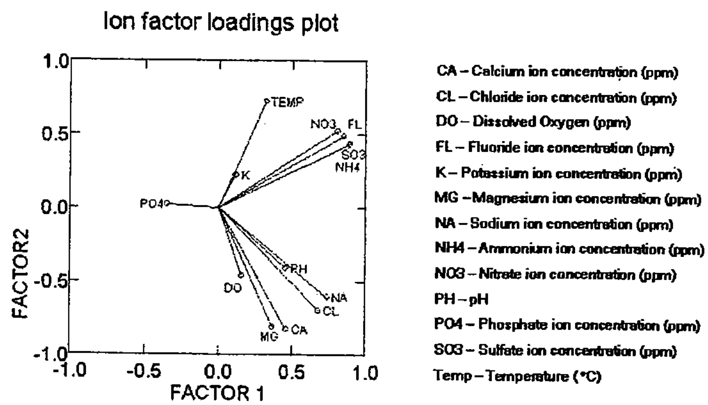

Figure 5 – Principal components factor analysis (PCA) for water chemistry data on Tenmile Creek, Albany County, NY for the months of May-September 2003. Eigen-values = 4.765 (1) 4.050 (2).

Invertebrate Sampling

Tenmile Creek and Patroon Creek supported dramatically different macroinvertebrate communities. A total of 29 families representing 11 orders were found at the five sample sites on Tenmile Creek (Table 1). The number of families in the EPT orders was higher in Tenmile Creek than in Patroon Creek. EPT values were consistent with EPT values measured by DEC on Tenmile Creek from 1997 samples and all fell within the slightly impacted to non-impacted criteria (Figure 6). At two sample locations

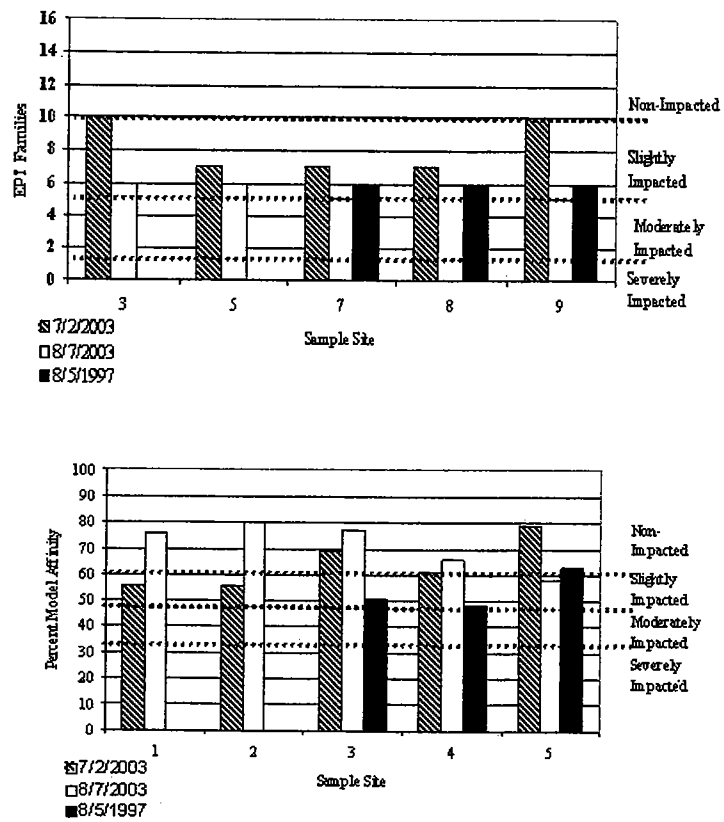

Figure 6 – EPT (Ephemeroptera, Plecoptera, Tricoptera) and PMA (percent model affinity) for macroinvertebrates at five sample sites on Tenmile Creek, Albany County, NY. Samples from August 5, 1997 are from a previous DEC study.

on Patroon Creek sampled by DEC in 1994 and during this study, no representative families of Plecoptera and Ephemeroptera were found (Table 2). In the order Tricoptera,

Table 1 – Invertebrate orders and relative abundance of families represented in a one-hundred individual subsample from 5 sampling sites along Tenmile Creek July 2 and August 7, 2003.

		Sample Site7/2/2003				
Order	Family	3	5	7	8	9
Ephemeroptera						
	Baetidae	0.040	0.024	0.077	0.095	0.041
	Isonychiidae	*	*	0.019	0.021	0.041
	Ephemeridae	0.008	*	*	*	*
	Heptageniidae	0.040	0.061	0.048	*	0.031
	Ephemerellidae	*	*	*	*	0.093
	Leptophlebiidae	0.048	0.049	0.029	0.021	0.031
	TOTAL	0.135	0.134	0.173	0.137	0.237
Plecoptera						
	Perlidae	0.095	0.000	0.029	0.053	0.072
	Leuctridae	0.183	0.329	*	*	0.021
	TOTAL	0.278	0.329	0.029	0.053	0.093
Tricoptera						
	Philopotamidae	0.190	0.134	0.096	0.011	*
	Polycetropodidae	0.024	*	*	*	*
	Hydropsychidae	0.008	0.098	0.067	0.126	0.052
	Hydroptilidae	0.016	0.024	*	*	0.010
	Glossosomatidae	*	*	*	*	*
	Brachycentridae	*	*	*	0.032	0.052
	TOTAL	0.238	0.256	0.163	0.168	0.113
Coeoptera						
	Psephenidae	0.159	*	0.077	0.042	0.124
	Elmidae	0.008	0.024	0.010	0.105	0.031
	TOTAL	0.167	0.024	0.087	0.147	0.155
Megaloptera						
	Corydalidae	*	*	0.058	*	0.082
	TOTAL	*	*	0.058	*	0.082
Odonata						
	Aeshnidae	*	*	*	*	0.010
	Gomphidae	*	*	*	*	*
	TOTAL	*	*	*	*	0.010
Diptera						
	Chironomidae	0.103	0.207	0.433	0.474	0.216
	Tipulidae	0.024	0.012	*	0.011	0.010
	Empididae	0.008	*	0.048	*	0.031
	Athericidae	*	*	*	*	*
	TOTAL .	0.135	0.220	0.481	0.484	0.258
Hemiptera						
	Veliidae	*	*	*	0.011	*
	Saldidae	*	*	*	*	*
	TOTAL	*	*	*	0.011	*
Decapoda						
	Cambaridae	0.040	0.024	*	*	*
	TOTAL	0.040	0.024	*	*	*
Mollusca						
	Unknown Mollusca	*	*	*	*	0.010
	TOTAL	*	*	*	*	0.010
Annelida						
	Lumbriculidae	*	0.012	*	*	*
	Unknown Annelida	*	*	*	*	*
	TOTAL	*	0.012	*	*	*
Misc Pupae						
	TOTAL	0.008	*	0.010	*	0.041

		Sample Site 8/7/2003				
Order	Family	3	5	7	8	9
Ephemeroptera						
	Baetidae	0.020	*	0.010	0.019	0.065
	Isonychiidae	*	*	*	*	0.000
	Ephemeridae	*	*	*	*	0.000
	Heptageniidae	0.248	0.280	0.283	0.135	0.009
	Ephemerellidae	*	*	*	*	0.000
	Leptophlebiidae	*	*	*	*	0.000
	TOTAL	0.267	0.280	0.293	0.154	0.075
Plecoptera						
	Perlidae	0.040	0.100	0.071	0.048	0.075
	Leuctridae	*	0.010	*	*	0.000
	TOTAL	0.040	0.110	0.071	0.048	0.075
Tricoptera						
	Philopotamidae	0.020	0.010	0.091	0.029	0.000
	Polycetropodidae	*	*	*	*	0.000
	Hydropsychidae	0.099	0.180	0.051	0.019	0.037
	Hydroptilidae	*	*	*	0.010	0.000
	Glossosomatidae	0.010	0.010	*	*	0.009
	Brachycentridae	*	*	*	*	0.000
	TOTAL	0.129	0.200	0.141	0.058	0.047
Coeoptera						
	Psephenidae	0.297	0.060	0.020	0.125	0.196
	Elmidae	0.010	*	0.010	0.038	0.009
	TOTAL	0.307	0.060	0.030	0.163	0.206
Megaloptera						
	Corydalidae	0.020	0.040	0.162	0.077	0.093
	TOTAL	0.020	0.040	0.162	0.077	0.093
Odonata						
	Aeshnidae	0.020	0.010	*	*	0.000
	Gomphidae	*	*	*	0.010	0.000
	TOTAL	0.020	0.010	*	0.010	0.000
Diptera						
	Chironomidae	0.158	0.240	0.273	0.442	0.411
	Tipulidae	0.020	0.020	*	0.010	0.075
	Empididae	*	*	*	0.010	0.000
	Athericidae	*	*	0.010	0.010	0.000
	TOTAL	0.178	0.260	0.283	0.471	0.486
Hemiptera						
	Veliidae	*	*	*	*	0.000
	Saldidae	*	*	*	0.010	0.000
	TOTAL	*	*	*	0.010	0.000
Decapoda						
	Cambaridae	0.010	*	*	*	0.000
	TOTAL	0.010	*	*	*	0.000
Mollusca						
	Unknown Mollusca	0.010	*	*	*	0.000
	TOTAL	0.010	*	*	*	0.000
Annelida						
	Lumbriculidae	*	0.010	*	*	0.000
	Unknown Annelida	*	*	*	*	0.000
	TOTAL	*	0.010	*	*	0.000
Misc Pupae						
	TOTAL	0.020	0.030	0.020	0.010	0.019

Table 2 – Macroinvertebrate orders and relative abundances from a random subsample of one hundred individuals found at two sample sites on Patroon Creek, August 5, 2003. One hundred individuals were not obtained from Site 2, so the total sample of 26 was used.

	8/5/2003 Sample Site	
Order	1	2
Ephemeroptera	*	*
Plecoptera	*	*
Tricoptera	0.232	0.538
Coleoptera	0.071	*
Megaloptera	*	*
Odonata	*	*
Diptera	0.091	0.077
Hemiptera	*	*
Decapoda	0.02	*
Amphipoda	0.222	0.115
Mollusca	0.141	0.155
Annelida	0.212	0.077
Platyhelminthes	0.011	0.038
Sample size	99	26

two families were found in 1994 and one family was found in 2003. When seven major invertebrate orders from invertebrate samples were compared to a model pristine community (Bode et al. 2002), Tenmile Creek exhibited percent model affinity (PMA) values higher than Patroon Creek, where higher values signify less impacted communities. For both EPT and PMA, Patroon Creek fell into the severely to moderately impacted category (Figure 7).

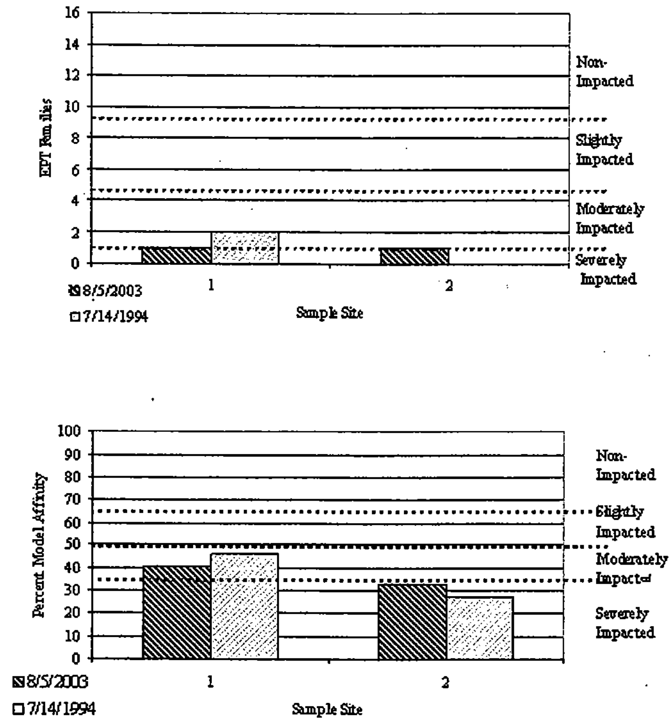

Figure 7 - EPT (Ephemeroptera, Plecoptera, Tricoptera) and PMA (percent model affinity) for macroinvertebrates at two sample sites on Patroon Creek, Albany County, NY. Samples from July 14, 1994 are from a previous DEC study.

On the basis of family composition, invertebrates at sample sites above Lake Myosotis clustered apart from samples below the lake (Figure 8A). On the basis of relative abundances among families, the clustering pattern was similar, delineating sites above Myosotis and below the hamlet, but corresponded more closely to site order (Figure 8B).

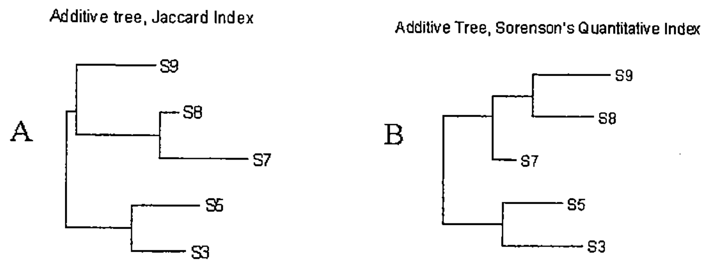

Figure 8 – Cluster diagram based on Jaccard (A) and Sorenson's Quantitative (B) Indices for invertebrates in Tenmile Creek, Albany County, NY. S3 and S5 are sample sites above Lake Myosotis, S7 is below the lake but above the Hamlet of Rensselaerville, and S8 and S9 are below the hamlet.

DISCUSSION

All water quality indicators demonstrate that the two watersheds are extremely different. Over a four month period (May – September 2003), significant differences in major ion concentrations were detectable between the urban and the well-forested watersheds. Patroon Creek exhibited higher ion concentrations with greater variability than Tenmile Creek. Higher levels of magnesium and calcium could be a result of ions running off from building materials, such as asphalt and concrete. Sodium and chloride ion concentrations, 10 to 20 times higher in Patroon Creek, are best explained by residual road salt from winter applications. The large area of impervious surfaces along Patroon

Creek increases the amount of storm water run-off reaching the creek and may therefore be a force driving higher ion concentration in the creek and lower water quality. Unlike high nutrient levels commonly encountered in streams that drain agricultural and suburban watersheds, levels of nitrate, phosphate, sulfate, and ammonium are relatively low in Patroon and Tenmile Creeks. Patroon Creek watershed is so heavily urbanized, it receives little non-point source inputs from agriculture or lawns. Very little active agriculture is present in Tenmile Creek watershed, and any agriculture that is present may be offset by the presence of riparian forest able to slow run-off and sequester nutrients.

Within Tenmile Creek, the impoundment at Lake Myosotis and the Hamlet of Rensselaerville appear to explain some of the variation in ion concentration. Sodium and chloride ion concentration showed similar significant increases after Lake Myosotis and again after the hamlet. As with Patroon Creek, residual road salt may best explain these increases in sodium and chloride as the creek approaches the hamlet. Magnesium and calcium ion concentration did not increase after the impoundment, but did significantly increase after the hamlet. Rensselaerville is in the process of switching from septic to sewage treatment, and slight increases in calcium can sometimes be attributable to septic or sewage contamination.

The choice of Tenmile Creek as a reference seems well supported. The geographic proximity and similar size of the creek to Patroon Creek, coupled with the contrasting land-use make for interesting comparison. The two creeks supported different communities of macroinvertebrates. According to EPT and PMA indices used by New York State DEC, Patroon Creek invertebrates represented a severely to moderately impacted stream, with no noticeable improvements between the sampling

DEC performed in 1994 and sampling for this study in 2003. In contrast, Tenmile Creek EPT and PMA values indicate a slightly to non-impacted system. These data were consistent with data collected by DEC in July 1997. Invertebrate data support the comparison of Patroon Creek as a severely impacted system to Tenmile Creek as a relatively non-impacted system. Differences in land use between the watersheds most likely explain these observed differences in invertebrates, as well as ion concentrations.

Additive trees generated using Jaccard Index and Sørenson's Quantitative Index exhibited similar clustering of invertebrate families in Tenmile Creek with regards to the three major spatial groupings: above the lake, below the lake but above the hamlet, and below the hamlet. The Jaccard Index, which takes into account only presence/absence, showed clustering of sites related to the three spatial groupings. Samples above Lake Myosotis were similar and differed significantly from those below the lake. Site 9, the farthest downstream was different from the sites above and directly below the hamlet. Sørenson's Quantitative Index, which weights presence/absence with relative abundance, fell into similar clustering. Sample sites above the lake were different from those below the lake. Sample sites below the hamlet were clustered from those above. These invertebrate data exhibit a strikingly similar pattern to spatial differences observed in ion concentration.

Although differing land-use within the watersheds is a clear factor affecting water quality, precise measurements of riparian buffer width and impervious surface area were not performed in this study. Within Tenmile Creek, the impoundment at Lake Myosotis and inputs from the Hamlet of Rensselaerville have some affect on ion concentration and invertebrate community, as supported by the clustering of data found in this study.

However, the creek undergoes a shift in bedrock geology after the lake and before the hamlet from Kiskatom Formation shale and sandstone to Lower Hamilton Group shale and siltstone (USDA 1992). It is unclear if the change in bedrock accounts for any of the increases in magnesium and calcium ion concentration. A change in bedrock could explain the strong correlations evident in the PCA factor analysis. In the PCA, ions separated out into groupings of more alkaline associated ions (Mg and Ca) and more acidic associated ions (nitrate and sulfate). This suggests that alkalinity or pH may be a major factor in the correlation.

During the month of May, prominent spikes in nitrate, sulfate, phosphate, and ammonium levels were detected below Lake Myosotis. However, concentrations were far lower during the next three sampling months. Lake Myosotis is known to be eutrophic, has a history of herbicide use to keep weed levels down, and has built up a bottom layer of organic material. If a high spring flow caused a scouring or a turnover in the lake, nutrients from this organic layer could have appeared in the sample.

Patroon Creek watershed and Tenmile Creek watershed are clearly very different systems. The urban creek tends to have higher concentrations of dissolved ions and more depauperate invertebrate communities than the well-forested creek. However, this study represents only four months of water quality data, and it is difficult in such a short time span to determine whether the data simply reflect seasonal variation.