The Effects of Physical and Chemical Water Quality Parameters on the Distribution of Aquatic Invertebrates within the Carmans River on Long Island, New York.

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Abstract

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While the Carmans River is one of a few pristine aquatic ecosystems on Long Island, roadside run-off, fertilizers, septic systems and groundwater contaminants all threaten to degrade its condition. All of these factors directly affect water quality and the distribution of aquatic invertebrates, which, in turn, affect higher trophic levels. Sensitive populations such as invertebrate species serve as indicators of biological integrity and can be useful for identifying problems in water quality. This research is the initial investigation of a longitudinal study and will be used for planning mitigation projects. The physical and chemical variations in water quality were compared for six different locations and among three habitat types selected along the Carmans River. Water samples taken at each location were then tested in areas of varying water velocities. A Yellow Spring Instruments, Inc. (YSI) 650 MDS water quality meter was used to measure the real-time data for temperature, pH, dissolved oxygen, conductivity, and turbidity. Water samples were analyzed using a HACH Company Digital Titrator and colorimeter. Using a Surber sampler, aquatic invertebrate samples were collected, preserved, and then sorted and identified using a compound light microscope and taxonomic keys. Rapid bioassessment, another technique used to assess invertebrate diversity provided supplementary data needed to create a more accurate biodiversity index. By comparing the data collected from each site, invertebrate distributions were correlated with environmental parameters. The Carmans River and the biodiversity that it supports has been identified as a key natural resource on Long Island by several groups including the U.S. Fish & Wildlife

Service, the Environmental Defense Fund, the Nature Conservancy, and the New York State Department of Environmental Conservation. The results from this experiment showed that with movement downstream, the diversity of invertebrates increases with increasing habitat complexity, as expected. Also, from our data it can be concluded that upstream locations are more affected by runoff and other sources of contaminants than downstream locations. Using data from this initial investigation, areas of concern can be targeted for future projects to improve the water condition of the Carmans River.

Introduction

The Carmans River is one of the few freshwater ecosystems located within central Suffolk County of Long Island, New York. Flowing from north to south, the first eight miles of the river consists of fresh water. The last two miles, the river becomes an estuary leading into the Great South Bay. The Carmans River gets its fresh water directly from groundwater outflow. Although it is a suitable habitat for a variety of species, many different forms of development have threatened the Carmans River [5]. Human activities in the drainage basin (land clearing, industry, fertilization, etc.) as well as direct human effects on fresh waters (e.g., dams, water extraction, industrial and domestic effluents, fishing, introductions of alien species) have strong impacts on the freshwater landscape [10]. These actions may have direct consequences on disturbing water quality as well as macroinvertebrate distribution and biodiversity along the Carmans River.

Aquatic insects have been a major focus of ecological studies in freshwater habitats for over 100 years. Because macroinvertebrates integrate the effects of short-term environmental variations, they can serve as indicators of biological integrity. Most species have a complex life cycle of approximately one year or more. Sensitive life stages will respond quickly to stress; but the overall community will respond more slowly. Most state water quality agencies that routinely collect biosurvey data focus on macroinvertebrate distributions [7].

Invertebrate populations play important roles in the functioning of freshwater ecosystems and directly affect human welfare. Invertebrates regulate rates of primary production, decomposition, water clarity, thermal stratification, and nutrient cycling in lakes, streams, and rivers, as well as play a vital role in the food web [6]. They are the primary food of many freshwater fish [3] and many other vertebrates that live in or around the water [4]. Macroinvertebrate assemblages are good indicators of localized conditions because many have limited migration patterns or a sessile mode of life. They are also particularly well-suited for assessing site-specific impacts (upstream-downstream studies) [7].

The water quality-based approach to pollution assessment requires various types of data. Biosurvey techniques, such as the rapid bioassessment protocols (RBPs), are best used for detecting aquatic life impairments and assessing their relative severity [11]. Habitat quality is an essential measurement in any biological survey because aquatic fauna often have very specific habitat requirements independent of water-quality composition [1]. Habitat alteration is a primary cause of degraded aquatic resources. Preservation of an ecosystem's natural physical habitat is a fundamental requirement in maintaining diverse, functional aquatic communities in surface waters [8].

The intention of this investigation was to conduct a comprehensive assessment of invertebrate biodiversity and correlate invertebrate distributions with water quality within the Carmans River [5]. A variety of techniques were used to obtain data for evaluating the biodiversity of benthic macroinvertebrates. After analyzing the acquired data, the similarities and differences among the six sites and three habitats selected along the river were compared (Figure 1). Habitats were selected based upon water velocity measurements.

Figure 1 Monitoring locations on the Carmans River.

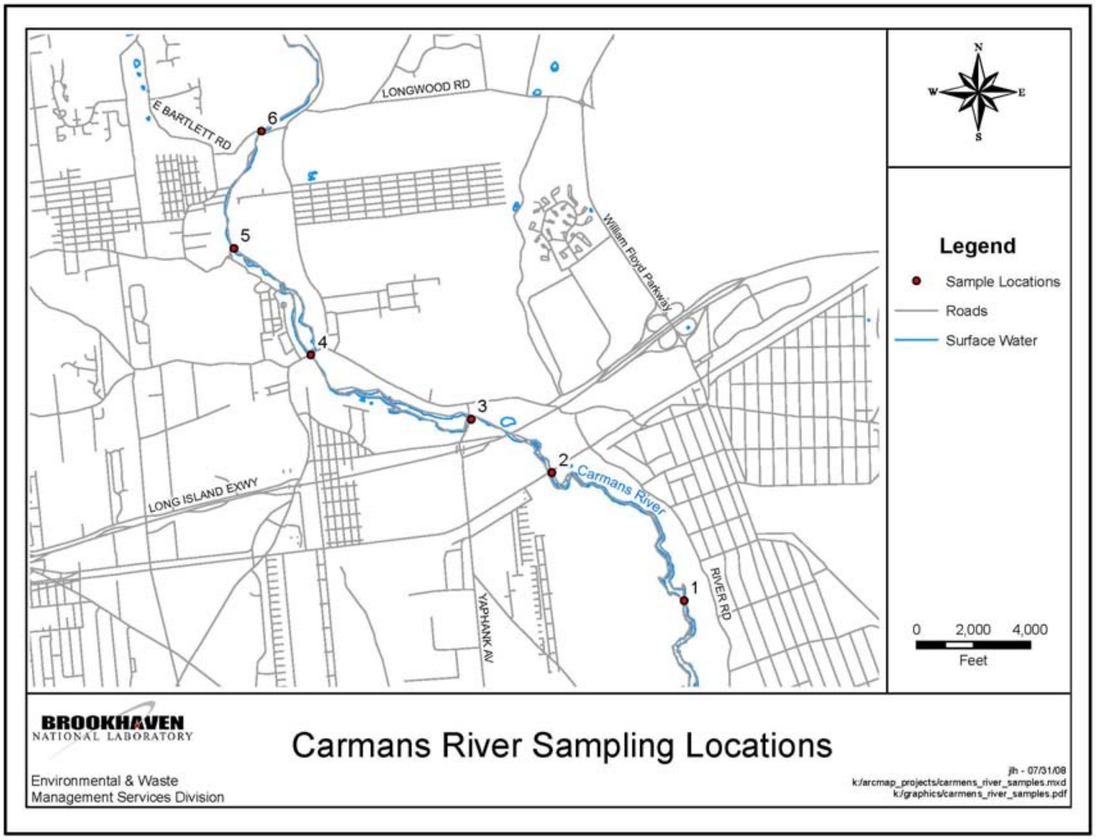

Table 1 Site locations from figure 1 and corresponding site number.

Location	Site
C-Gate Dam	1
Train Trestle	2
Lower Lake Dam	3
Upper Lake Dam	4
Warbler Woods	5
East Bartlet	6

Materials and Methods

A global positioning system (GPS) Magellan MobileMapper CE was used to map six locations along the first eight-mile stretch of the Carmans River. Once the sites were selected they were mapped using ArcInfo Geographic Information Systems (GIS).

Water Quality

A Yellow Spring Instruments, Inc. (YSI) model 650 MDS probe was used to obtain field data on pH, turbidity, conductivity, dissolved oxygen (DO) and temperature at the site locations weekly. The average was calculated for each parameter at each site. The YSI was re-calibrated weekly to ensure data accuracy. The average water velocit for the habitats (riffles, runs, and pools) at each site was measured using the Flow Probe (FP101). The average water velocity was then calculated for each habitat using data from all six sites.

Water Chemistry

Water samples were obtained weekly for six weeks at each site and habitat. In the laboratory the samples were analyzed using a HACH Digital Titrator Model 16900 and tested for nitrite, nitrogen, alkalinity, acidity, calcium (Ca) and magnesium (Mg) hardness, and total hardness. Analysis for low range nitrite along with Nitrogen (NO3) was accomplished using a HACH kit model DR 890 colorimeter. Routine procedures were followed from the manual for each test. Average, standard deviation, and variance were calculated from the data determined for each test.

Full Sample Invertebrate Assessment

Aquatic invertebrate samples were obtained using a Surber stream bottom sampler at each site and habitat. Three separate locations were selected in each habitat in which the Surber sampler was placed to collect sediment always moving from downstream to upstream to prevent contamination of samples. The samples were placed in plastic containers labeled with a number that correlated to the site and brought back to the laboratory. Samples were carefully sifted using a standard testing sieve from 180 micrometers down to 45. This method removes large rocks and debris to provide a cleaner sample to pick from. The samples were placed into 70% ethanol (ETOH). The aquatic invertebrates were picked from the sediment using a Nikon SMZ800 compound microscope and then sorted into groups by taxonomic order. Specimens were placed in labeled vials with 70% ETOH solution. The biodiversity was calculated for each site and habitat using the Shannon Index:

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Rapid Bioassessment

A rapid bio-diversity assessment was preformed following full sample analysis. The Surber stream bottom sampler was used to gather the samples at each site and habitat. A 6 by 4 grid with $2in^2$ squares was drawn on a flat sorting pan, which was used to spread the collected sample. The grid squares were randomly selected using a stopwatch and the aquatic invertebrates were counted up to 100 total. The data was placed on field count sheets by taxonomic orders for each location and the number of squares used was recorded. The count was then converted using a comparative percentage to the full aquatic invertebrate sampling method. This method was then repeated for a second trial. The biodiversity for trials one and two in each habitat were calculated using the Shannon diversity index.

Results

Water Quality

Water quality data collected weekly was averaged for each location along the Carmans River. The averages for temperature, conductivity, dissolved oxygen, pH, and turbidity are shown in Table 2. The averages for conductivity and DO show a decreasing trend from site 1 to site 6, from downstream to upstream, where as pH and Turbidity shows an increasing trend starting from site 1 upstream to site 6. Average temperature seems to increase from site 1 to site 4, and decreases from site 5 to 6 (Table 2).

The average water velocity decreases from the riffles, to runs, to pools (Table 3). The riffles have the highest water velocity at 2.34 ft/sec, runs have a moderate velocity of 1.17 ft/sec, and pools have a low water velocity of 0.41 ft/sec. The minimum and maximum velocities also decrease from riffles to runs to pools (Table 3).

Water Chemistry

Figure 2 demonstrates an increasing trend of average nitrate concentration in water samples from site 1 to site 6. The highest concentration of nitrate is at the most upstream location in the Carmans River, at 0.016 mg/l, and the lowest is at the most downstream location, at 0.006 mg/l. Nitrogen concentration also follows an increasing trend from site 1 to site 6, the highest concentration of nitrogen is upstream and the lowest measured concentration is downstream (Figure 3).

Figure 4 shows the averages for calcium and magnesium hardness, which make up the total water hardness. Calcium hardness and magnesium hardness tend to follow a linear trend with little fluctuation between sites. Total hardness appears to be the highest at sites 3 and 4 at an average of 40 mg/l and the lowest at sites 1 and 6 with an average hardness of 38.3 mg/l at site 1 and 34.4 mg/l at site 6. Figure 5 compares the acidity and alkalinity of water samples from sites 1 through 6. Alkalinity concentration shows a slight bell curve. Alkalinity increases from site 1 to site 3 with a peak from site 3 to 4 and decreases from site 4 to 6. Acidity concentration decreases from site 1 to site 3 with the lowest concentration between 3 and 4 and increases from site 4 to 6. The line graph shows an inverse relationship between alkalinity and acidity concentrations.

Aquatic Invertebrate Distribution

Diversity indices were calculated for each full sample based on the macroinvertebrate taxonomic order. In table 7 the number of individuals in each order is cited for each habitat and location from full sample analysis along the Carmans River. Biodiversity tends to decrease from site 1 to site 6 (Table 4). The biodiversity is the highest at site 1 which is the most downstream location and the lowest at site 6, which is the most upstream location on the Carmans River. Generally, pool habitats have the lowest diversity index out of the three habitats.

Diversity indices for trials one and two for the rapid bioassessment method of invertebrate sampling also shows an decreasing trend from upstream samples to downstream samples (Tables 5 & 6). Samples taken on 7/28/08 during trial two followed heavy rain and thunderstorms, which caused the river to swell.

Discussion

Water Quality

The Carmans River must meet a higher standard than other related fresh water tributaries because its ecosystem is populated with heritage native brook trout. Table 2 shows that the average DO has never been drastically lower than 7.0 mg/L except for site 6 which had experienced an average DO level of 6.9 mg/l as the standards recommend [2]. For rivers that fall into the “AA” category such as the Carmans River, the pH standards should never be greater than 8.5 nor lower than 6.5 [2]. All six sites were discovered to have pH averages that perfectly fell into the standard range that had to be met. The pH modestly decreased overall from one site to another, downstream to upstream (Table 2). Turbidity also reasonably increased from downstream to upstream. Concerning the regulations set by the New York State Department of Environmental Conservation, for turbidity, there shall be no increase that will cause substantial visual contrast to natural conditions [2]. The Carmans River at each location had average ranges between 27.0 NTU-29.8 NTU. With movement downstream the pH and turbidity decreases as the DO increases. These alterations could be due to a larger amount of run-off entering the sites located further upstream. The high levels of turbidity could be due to human activities, variation due to the weather, or phytoplankton growth, which increases the sediment content in the water. Sites 4 and 6, which were contaminated with the highest readings of turbidity, are located right beside impermeable roads. The more run-off that reaches the water, the higher the turbidity and the lower the DO becomes. “Non-point sources in residential development areas can have larger negative impacts on water quality than urban point sources.” [12] Conductivity on the other hand steadily increased downstream except for site 6 which decreased. Storm run-off could have impacted the waters natural conductivity readings at that precise location.

Water Chemistry

The findings for nitrite and ammonia/nitrogen levels were dramatically lower than the standard averages recommended by the EPA. The ammonia/nitrogen standards indicate that readings should not be higher than 2.000 mg/L while the nitrite should be no higher than 1.000mg/L [2]. This indicates that the Carmans River is generally well protected from excess fertilizers that might have reached the water. There is a noticeable higher value for both nitrite and ammonia nitrogen within site 6 because of the abundant amount of run-off it receives from the roadside (Figures 2 & 3). As for the acidity and alkalinity, there is a clear inverse relationship between the averages as seen in Figure 5. The calcium and magnesium hardness, which compensate for the total hardness have relatively low averages for all six sites (Figure 3). Together, the calcium and magnesium hardness act as a buffer to stabilize the acidity and alkalinity of the river. If for some reason an excess amount of acid were to be introduced to the water, the amount of total hardness and the neutral pH would not be enough to counteract and buffer against it. This leaves the river vulnerable to such an event and could result in the release of other cat ions such as aluminum, which could become toxic. Increased acid inputs over time may also alter pH as buffering systems are depleted.

Invertebrate Distribution Assessment

The invertebrate distribution results using the Shannon-Weiner equation showed a general trend that as velocity increases between habitat types (riffle, run, and pool), diversity and richness also increases. As expected, the diversity of benthic macroinvertebrates increases with water movement downstream (Table 4). This is due to the increasing complexity of microhabitats downstream from the water source. Increased habitat complexity has generally been found to increase species richness and diversity at whatever spatial scales, both in freshwater and in terrestrial communities [9]. Generally, the pool habitats were less diverse than the riffle and run habitats; the diversity indices were closer to zero. The location of site 6 at East Bartlet could have an effect on the invertebrate diversity because of direct runoff of roadside contaminants. It is evident that the nitrite and nitrogen concentrations were significantly higher at this site than at the other five. Surrounding catchment and isolation of certain sites can account for fluctuations in chemical composition due to presence or absence of roadside and agricultural inputs.

The rapid bioassessment method for collecting macroinvertebrates provided less definitive results. Trials 1 and 2 were comparable, each site and microhabitat had similar diversity indices for both. All samples taken on July 28th, 2008 followed heavy rains and thunderstorms, which caused a surge of water flow. This could account for the lower invertebrate diversity results for sites 4, 5, and 6, which are all upstream. Invertebrates from samples at sites 1, 2, and 3 could have drifted downstream due to the disturbance. As compared to the full sample invertebrate analysis, the rapid bioassessment results showed the same trend. The diversity increased with water flow downstream as complexity of microhabitats increased (Figures 5 & 6). This method did show less diverse samples than the full invertebrate sample results. This is most likely because the rapid bioassessment data, although the numbers are corrected to correlate with the full sample, are only a fraction of the full sample. Also, invertebrates that are smaller in size are not easily seen without the use of a microscope.

Future Work

This research is the initial investigation of a longitudinal study, which may be used for management of the Carmans River. There are plans to examine the sites and see if there is any variation between seasons. Future planning will focus on recapping the six designated sites annually concluding if there are any variations in water quality, water chemistry, and/or macroinvertebrate biodiversity.

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Tables and Figures

Table 2 averages for temperature, conductivity, dissolved oxygen, pH, and turbidity collected for each location along the Carmans River using the YSI 650 MDS water quality meter.

Site	Location	Temperature (°C)	Conductivity (us/cm²)	DO (mg/l)	pH	Turbidity (NTU)
1	C-gate Dam	18.9	186.1	10.6	6.6	27.0
2	Train Trestle	21.7	161.8	9.3	6.9	27.6
3	Lower Lake Dam	24.1	152.8	8.9	7.1	27.5
4	Upper Lake Dam	24.9	154.2	9.7	7.3	29.8
5	Warbler Woods	17.5	149.8	8.6	7.2	28.3
6	East Bartlet	19.5	173.8	6.9	7.2	29.2

Table 3 shows the average, minimum, and maximum water velocity for each habitat type.

Habitat	Average Velocity (ft/sec)	Minimum Velocity (ft/sec)	Maximum Velocity (ft/sec)
Riffle	2.34	0.90	4.34
Run	1.17	0.42	2.44
Pool	0.41	0.00	1.03

Table 4 diversity indices for the macroinvertebrates per full sample. The diversity is shown for each habitat within all six sites.

Site	Habitat	Diversity Index
1	Riffle	2.19
1	Run	1.71
1	Pool	1.90
2	Riffle	2.01
2	Run	2.30
2	Pool	1.74
3	Riffle	1.69
3	Run	2.02
3	Pool	1.65
4	Riffle	1.10
4	Run	1.51
4	Pool	1.73
5	Run	1.87
5	Pool	1.45
6	Riffle	1.57
6	Run	0.42
6	Pool	1.12

Tables 5 & 6 show the diversity indices for trials 1 and 2 of the rapid bioassessment of macroinvertebrates in the Carmans River. The diversity indices are listed for sites 1 through 6 in each habitat type.

Table 5 Trial 1

Site	Habitat	Date	Diversity
1	Riffle	7/23/08	1.62
1	Run	7/23/08	1.67
1	Pool	7/23/08	1.84
2	Riffle	7/23/08	2.15
2	Run	7/23/08	1.98
2	Pool	7/23/08	1.58
3	Riffle	7/24/08	1.62
3	Run	7/24/08	1.62
3	Pool	7/24/08	1.95
4	Riffle	7/24/08	1.53
4	Run	7/24/08	1.45
4	Pool	7/24/08	1.56
5	Run	7/25/08	1.60
5	Pool	7/25/08	0.96
6	Riffle	7/25/08	1.65
6	Run	7/25/08	1.03
6	Pool	7/25/08	0.95

Table 6 Trial 2

Site	Habitat	Date	Diversity
1	Riffle	7/28/2008*	1.57
1	Run	7/28/2008*	1.17
1	Pool	7/28/2008*	1.42
2	Riffle	7/28/2008*	1.15
2	Run	7/28/2008*	2.21
2	Pool	7/28/2008*	1.57
3	Riffle	7/28/2008*	1.79
3	Run	7/28/2008*	1.86
3	Pool	7/28/2008*	1.68
4	Riffle	7/29/08	1.15
4	Run	7/29/08	0.79
4	Pool	7/29/08	1.48
5	Run	7/29/08	1.19
5	Pool	7/29/08	0.97
6	Riffle	7/29/08	1.46
6	Run	7/29/08	1.30
6	Pool	7/29/08	1.41

* sampling dates following river swelling due to extreme rain and thunder storms

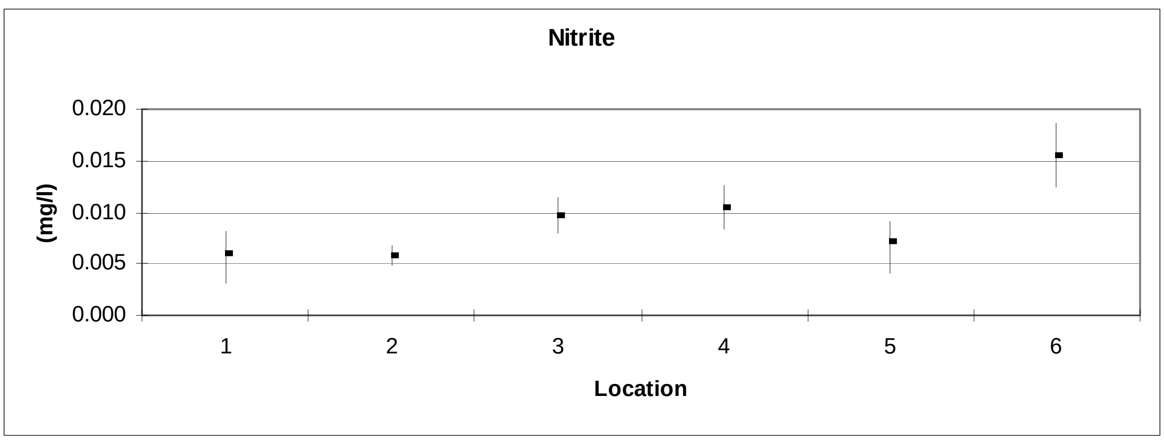

Figure 2 average nitrite levels with standard deviation for each of the six locations from the results of the water analysis using the HACH kit.

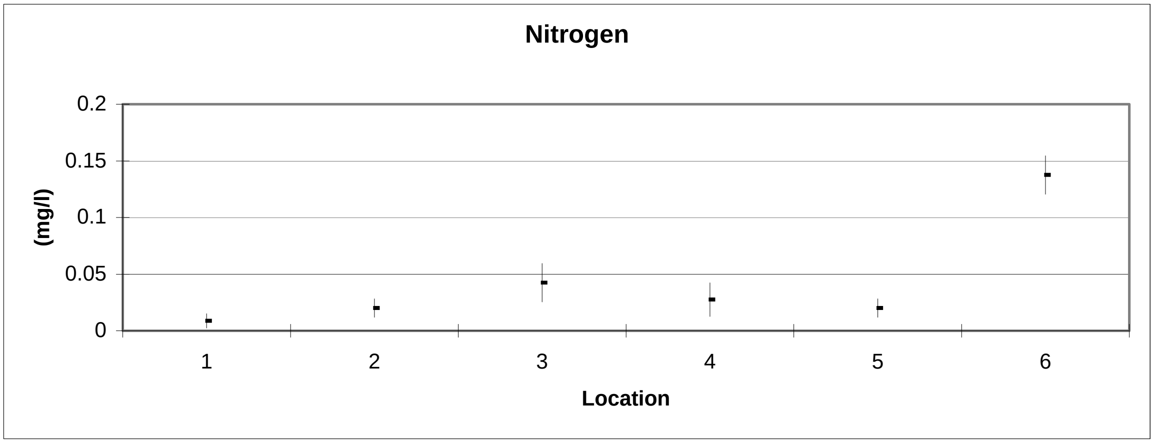

Figure 3 average nitrogen levels with standard deviation for each of the six locations from the results of the water analysis using the HACH kit.

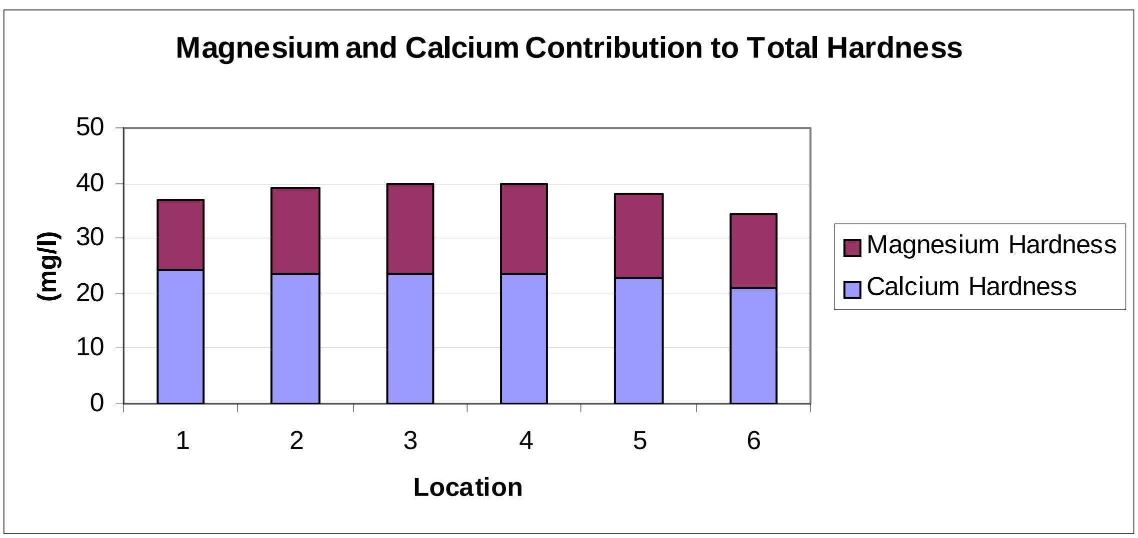

Figure 4 shows the average magnesium hardness and average calcium hardness at each site. Together these equal the total hardness. The values for each water sample were determined using the HACH kit digital titrator.

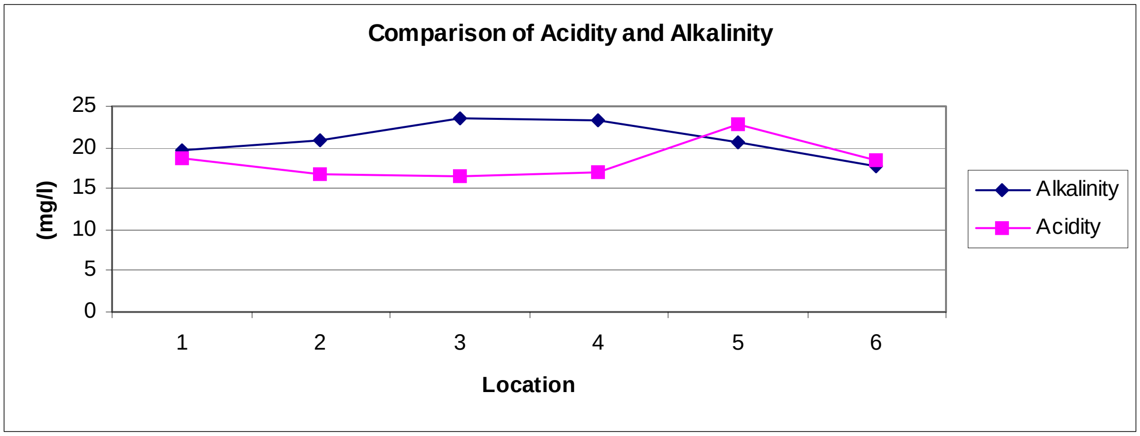

Figure 5 comparison of the alkalinity and acidity for water samples taken at each of the six locations along the Carmans River.

Table 7 number of individuals per taxonomic order in each habitat, sites 1 through 6. This is data collected from full sample invertebrate analysis

	Site 1			Site 2			Site 3			Site 4			Site 5		Site 6		
Taxon	Riffle	Run	Pool	Riffle	Run	Pool	Riffle	Run	Pool	Riffle	Run	Pool	Run	Pool	Riffle	Run	Pool
Anguilliformes	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Plecoptera	11	1	0	34	5	8	0	1	0	0	0	0	2	0	0	0	0
Odonata	5	20	5	11	1	0	2	0	3	1	2	1	1	1	0	0	1
Ephemeroptera	2	37	42	105	52	25	7	3	10	1	1	0	23	2	2	6	4
Coleoptera	25	0	0	23	2	6	273	11	4	19	11	2	5	0	0	2	0
Tricoptera	4	23	19	136	17	148	54	6	11	51	43	6	16	6	1	14	6
Diptera	43	296	214	80	39	40	172	47	165	295	124	8	24	0	3	27	55
Turbellaria	33	9	0	142	39	6	14	9	49	29	0	0	0	0	0	0	0
Oligochaeta	44	28	9	21	48	27	46	20	16	3	0	36	11	12	3	7	8
Megaloptera	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Hirudinea	6	13	26	0	0	4	0	0	4	0	0	2	2	0	0	2	5
Amphipoda	20	351	155	67	49	219	60	44	191	15	74	26	77	8	14	981	156
Gastropoda	1	18	48	0	3	4	35	24	3	5	8	1	3	1	0	2	0
Isopoda	7	47	28	15	71	51	4	4	25	2	7	2	24	0	19	20	301
Hemiptera	12	98	69	0	0	2	1	1	18	0	0	0	1	0	1	0	0
Bivalvia	0	0	9	0	0	2	4	11	0	1	12	30	0	0	1	2	0
Perciformes	0	0	3	0	0	4	0	0	1	0	0	0	0	0	0	0	0
Hydracarina	1	0	0	0	0	0	0	0	0	0	0	1	2	0	1	1	0