

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

Vicky Giese

Office of Science, Science Undergraduate Laboratory Internship (SULI)
California Polytechnic University

Mellissa Winslow

Office of Science, Science Undergraduate Laboratory Internship (SULI)
Clarkson University

Glen Bornhoft

Office of Science, Science Undergraduate Laboratory Internship (SULI)
SUNY Oneonta

Tim Green

Brookhaven National Laboratory
Upton, New York

August 7, 2009

Prepared in partial fulfillment of the requirements of the Office of Science, Department of Energy's Science Undergraduate Laboratory Internship under the direction of Timothy Green in the Natural Resources and Waste Management Division at Brookhaven National Laboratory.

Participant: _____

Participant: _____

Participant: _____

Research Advisor: _____

Table of Contents

Abstract	3
Introduction.....	5
Materials and Methods.....	6
<i>Water Quality</i>	7
<i>Water Chemistry</i>	7
<i>Full Sample Invertebrate Assessment</i>	7
<i>Rapid Bioassessment</i>	8
Results	9
<i>Water Quality</i>	9
<i>Water Chemistry</i>	9
<i>Aquatic Invertebrate Distribution</i>	10
<i>Invertebrate and Water Quality Correlation</i>	11
Discussion	12
<i>Water Quality</i>	12
<i>Invertebrate and Water Quality Correlation</i>	14
Literature Cited	15
Acknowledgements.....	16
Tables and Figures	17

Abstract

Vicky Lynn Giese (California Polytechnic University, San Luis Obispo, CA 93407),
Mellissa Winslow (Clarkson University, Potsdam, NY 13699), Glen Bornhoft (SUNY
Oneonta, Oneonta, NY 13820), Timothy Green, (Brookhaven National Laboratory,
Upton, NY 11973).

While the Carmans River is one of the few pristine aquatic ecosystems on Long Island, New York, roadside run-off, fertilizers, septic systems, and groundwater contaminants all threaten to degrade its condition. A study, then, that uses the physical and chemical variations of water quality in addition to benthic macro-invertebrate distributions can explore and demonstrate the ecological integrity of the Carmans River more accurately. Sensitive populations such as invertebrate species serve as indicators of biological integrity and can be useful for identifying problems in water quality. Using a Surber sampler, aquatic invertebrate samples were collected. Samples were then preserved, sorted, and identified using a compound light microscope and taxonomic keys. A YSI 650 MDS electronic water quality meter was used to measure the real-time water data. By comparing the data collected from each site, invertebrate distributions were correlated with environmental parameters. Annual variations were determined through a comparison of results from 2008 and 2009 data sets. The results from the data collected in 2008 showed that as the location of the collection site moved downstream and the habitat complexity increased the diversity of invertebrate's increased from an average diversity index of 1.03 to 1.93. The results from an ANOVA test showed with 90% confidence that the diversity between 2008 and 2009 data samples yielded the same result. There was no significant variation in nitrate, nitrite, or nitrogen/ammonia between sampling locations and, therefore, these are not contributing factors to changes in diversity. Upstream locations had lower DO levels, higher pH, and higher turbidity,

explaining why the diversity of invertebrates increased downstream in 2008. Activities such as sampling in the same locations at precise habitats or recreational kayaking, sport fishing, and other disruptions could have been an element in shifting the results. Seasonal sampling may be a more effective alternative to avoid skewed results. This would give the river a longer recovery time from sampling activities. Using data from this investigation, areas of concern can be targeted for future projects to improve 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 [1]. 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 [2]. These actions may have direct consequences on disturbing water quality as well as macro-invertebrate distribution and biodiversity along the Carmans River.

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 [3]. They are the primary food of many freshwater fish [4] and many other vertebrates that live in or around the water [5]. Macro-invertebrate 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) [6].

Aquatic insects have been a major focus of ecological studies in freshwater habitats for over 100 years. Macro-invertebrates integrate the effects of short-term

environmental variations and therefore 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 macro-invertebrate distributions [6].

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 [7]. Habitat quality is an essential measurement in any biological survey because aquatic fauna often have very specific habitat requirements independent of water-quality composition [8]. 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 [9].

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 [1]. A variety of techniques were used to obtain data for evaluating the ecological integrity of the river. Water quality, water chemistry, and invertebrate distributions were utilized in two consecutive years to determine the stability and health of the ecosystem in 2008 and 2009.

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. Six sites and three habitats within each site were selected along the river for sampling (Figure 1). Habitats

with the highest water velocities were labeled as riffles, moderate velocities were labeled runs, and the lowest velocities were deemed pools. 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, conductivity, dissolved oxygen (DO) and temperature at the site locations weekly. The YSI was re-calibrated weekly to ensure data accuracy. The average water velocity for the habitats (riffles, runs, and pools) at each site was measured using the Flow Probe (FP101).

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, ammonia, nitrate, alkalinity, acidity, calcium (Ca) and magnesium (Mg) hardness, and total hardness. In addition to the tests mentioned above, total reactive phosphorous, total suspended solids, and nitrate were tested in 2009 water samples. Analysis for low range nitrite, ammonia, phosphorous, suspended solids, and nitrate was accomplished using a HACH kit model DR 890 colorimeter.

Full Sample Invertebrate Assessment

Aquatic invertebrate samples were obtained using a Surber sampler at each site and habitat. Three separate locations were selected in each habitat in which the Surber sampler was placed to collect sediment. Samples were always taken from downstream to upstream to prevent cross-contamination. Samples were carefully sifted using a standard

testing sieve from 180 micrometers down to 45 in the laboratory. This method removes large rocks and debris to provide a cleaner sample to pick from. The aquatic invertebrates were picked from the sediment using a Nikon SMZ800 compound microscope and then sorted by taxonomic order. The samples were then preserved in 70% ethanol (ETOH). The biodiversity was calculated for each site and habitat using the Shannon Index (Equation 1).

Equation 1: Shannon Diversity Index

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

Where H' designates diversity, S indicates the number of species, i specifies the abundance of species, N relates to the total number of all individuals, and p_i is the relative abundance of each species.

Rapid Bioassessment

A rapid bio-diversity assessment was performed following full sample analysis. The Surber sampler was used to gather the samples at each site and habitat. A 6 by 4 grid with 2 in² 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 order 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 for 2008 and 2009. The averages for temperature, conductivity, dissolved oxygen, pH, and velocity are shown in Table 2. Although 2009 averages for DO are relatively higher than 2008 results, both years show decreasing trends from site 1 to site 6, from downstream to upstream. Average temperature increases from site 1 to site 4, and decreases from site 5 to 6 for both 2008 and 2009 (Table 2). Average pH readings hold a steady trend from one site to the next and rarely fluctuate. During the sampling period the turbidity probe of the YSI water quality meter was non-functional and therefore, no accurate turbidity readings were obtained.

The average water velocity decreases from the riffles, to runs, to pools (Table 3). In 2008 average velocity readings were the highest in the riffle at 2.34 m/sec, runs had a moderate water velocity of 1.17 m/sec, and pools had the lowest velocity of 0.41 m/s. In 2009 the riffles had the highest water velocity at 2.41 m/sec, runs had a moderate velocity of 1.21 m/sec, and pools had the lowest water velocity of 0.27 m/sec.

Water Chemistry

Figure 2 demonstrates an increasing trend of average nitrite concentration in water samples from site 1 to 6 in 2008. The highest concentration of nitrite was at the most upstream location in the Carmans River, at 0.016 mg/l, and the lowest at the most downstream location, at 0.006 mg/l for 2008. During 2009, the highest concentration for nitrite was downstream at site 1 along the Carmans River, at 0.016 mg/l, and the lowest at

site 3, at 0.006 mg/l. An increase in nitrite level in 2009 at site 1 was noted but the variance is small scale (Figure 2). Ammonia concentration also follows an increasing trend from site 1 to site 6, the highest concentration of nitrogen was upstream and the lowest measured concentration was downstream for 2008 and 2009 (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 for both 2008 and 2009 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 in 2008. Figure 5 compares the acidity and alkalinity of water samples from sites 1 through 6 for 2008. The alkalinity concentration shows a slight bell curve for 2008. 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 for 2008 (Figure 5). The alkalinity and acidity data for 2009 was inconclusive and therefore not used. The average phosphorous levels for 2009 are between 0.083 and 0.124 mg/l and the variance between sites was negligible (Figure 6).

Aquatic Invertebrate Distribution

Diversity indices were calculated for each full sample based on the macro-invertebrate taxonomic order. In figure 7, diversity indices from full samples 1 and 2, as well as from the rapid bioassessment procedure was correlated with habitat type. This gave a more concrete display of the ecological analysis between habitats along the

Carmans River. In 2008, biodiversity decreased from site 1 to site 6 (Figure 7). However, in 2009, there was not a significant difference in diversity between sites 1 through 6 (Figure 7). The full sampling technique provides relatively the same numbers as the rapid bioassessment technique even when distinguishing between habitats. There is not a consistent correlation between diversity results derived from a comparison of the sampling techniques (Figure 7).

Invertebrate and Water Quality Correlation

In order to determine the relationship between water quality and diversity the data was correlated with water temperature. Diversity and temperature had a negative correlation in the riffles and pools and a positive correlation in the runs. In the run habitats, there is a direct relationship between temperature and diversity (Figure 8). There is not a well defined relationship between temperature and diversity in the riffle and pool habitats (Figure 8).

From the water quality and invertebrate data collected in both 2008 and 2009 the diversity and velocity correlation was determined. Velocity can be positively correlated to diversity in the run and pool habitats and negatively correlated in the riffle habitats from 2008 data. In 2009 there was a positive correlation between velocity and diversity in all three habitats. Figure 8 does not show a well defined relationship between diversity and velocity in either sampling year.

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 was not lower than 7.0 mg/L for 2008 and 2009 except for site 6 in 2008 which experienced an average DO level of 6.9 mg/l [10]. DO readings from 2009 were considerably higher than 2008. 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 [10]. For 2008, all six sites were revealed to have pH averages that rightly fell into the standard range that had to be met. However, for 2009, pH readings were slightly more acidic than 2008 which may be due to the excessive amount of precipitation during June 2009. The pH modestly decreased overall downstream to upstream in 2008 while staying comparatively the same throughout all 6 sites in 2009 (Table 2). With movement downstream, the pH slightly decreases as the DO increases for both years. These alterations could be due to a larger amount of run-off entering the sites located further upstream. “Non-point sources in residential development areas can have larger negative impacts on water quality than urban point sources” [11]. In 2008, conductivity steadily increased downstream except for site 6 which decreased. In 2009 the averages for each site were within a smaller range than 2008. Storm run-off could have the potential to impact the waters natural conductivity readings within the river.

Water Chemistry

The findings for nitrite and ammonia levels were dramatically lower than the standard averages recommended by the EPA for both 2008 and 2009. The ammonia

standards indicate that readings should not be higher than 2.000 mg/L while nitrite should be no higher than 1.000 mg/L [10]. This indicates that the Carmans River is generally well protected from excess fertilizers. There is a noticeably higher value for both nitrite and ammonia within site 6 because of high levels of roadside run-off. The values of nitrite and ammonia were similar in 2008 and 2009. Although there was an increase in nitrite levels in 2009 at site 1, there was no significant variation between sites and therefore the variance is negligible (Figure 2). As for acidity and alkalinity, there is a clear inverse relationship between the averages as seen in Figure 5 for 2008. The acidity and alkalinity results for 2009 were inaccurate and therefore were not used. The calcium and magnesium hardness, which compensate for total hardness have relatively low averages for all six sites and show a similar trend from 2008 and 2009 (Figure 4). Together, calcium and magnesium hardness act as a buffer to stabilize the acidity and alkalinity of the river. If excess acids were to be introduced, the total hardness and neutral pH would not be enough to counteract and buffer against it. Increased acid inputs over time may also alter pH as buffering systems are depleted. The average phosphorous levels for 2009 are between 0.083 and 0.124 mg/l and the variance between sites are negligible (Figure 6). There is no evidence of excess nutrient runoff into the Carmans River within the sampling locations.

Invertebrate Distribution Assessment

In 2009, an ANOVA test was performed to correlate statistical differences between the diversity results from 2008 and 2009. The outcome of the ANOVA test showed a 90% confidence interval that all samples in 2008 and 2009 were the same. The variance of 2009 diversity is much less than the variance of diversity in 2008.

When compared to the full sample invertebrate analysis, the rapid bioassessment results showed the same trends in 2008. It was assumed that the diversity increased with water flow downstream as complexity of microhabitats increase. Increased habitat complexity has generally been found to increase species richness and diversity at whatever spatial scales, in both freshwater and terrestrial communities [12]. Rapid bioassessment data from 2008 showed less diverse samples than the full invertebrate sample. This is most likely because the rapid bioassessment technique represents only a fraction of the full sample. Irregular data in 2009 could have been the byproduct of disturbances to the river bed. Activities such as sampling in the exact same locations, kayaking, fishing, and other disturbances could have yielded inaccurate results. Seasonal sampling may be a more effective alternative which would give the river a longer recovery time between sampling activities.

Invertebrate and Water Quality Correlation

The statistical analysis for diversity and water temperature did not show a high correlation between the two parameters. It is evident that the upper and lower lakes which raised the average temperature of water under the dam have an effect on the diversity of riffles and pools but do not significantly affect the diversity of the run habitats (Figure 8). It is possible that the biota will react differently to temperature based on the habitat type. Flaws in sampling techniques and spatial distribution of sampling periods could alter the results.

There was also not a significant correlation between diversity and velocity by habitat for 2008 and 2009 (Figures 9 and 10). This could also be due to flaws in sampling which may cause unintended disturbances to the benthic habitat. In order to

achieve more accurate results sampling periods should be spread across a longer time frame. Seasonal sampling may be less disruptive and will allow the benthic habitat to recover. Future planning will focus on recapping the six designated sites concluding if there are any variations in water quality, water chemistry, and/or macro-invertebrate biodiversity.

Literature Cited

- [1] Green, T. "A Proposal to The Long Island Community Foundation Henry Phillip Kraft Memorial Fund Carmans River Project." Foundation for Ecological Research in the Northeast, pp. 1-3, 2008.
- [2] Strayer, D. Challenges for Freshwater Invertebrate Conservation. *Journal of the North American Benthological Society*, 25, pp. 271-287, 2006.
- [3] Mazumder A., Taylor W. D., McQueen D. J., and Lean D. R. S. Effects of fish and plankton on lake temperature and mixing depth. *Science*. 247, pp. 312–315, 1990.
- [4] Gerking S. D. Feeding ecology of fish. Academic Press, San Diego, California, 1994.
- [5] Gray L. J. Response of insectivorous birds to emerging aquatic insects in riparian habitats of a tallgrass prairie stream. *American Midland Naturalist*. 129, pp. 288–300, 1993.
- [6] Southerland, M.T. and J.B. Stribling. Status of biological criteria development and implementation. *Biological assessment and criteria: Tools for water resource planning and decision making*. Lewis Publishers, Florida, 1995.
- [7] U.S. Environmental Protection Agency (U.S. EPA). *Technical support document for water quality based toxics control*. U.S. Environmental Protection Agency, Office of Water, Washington, D.C. EPA 505-2-90-001, 1991.
- [8] Barbour, M.T., J. Gerritsen, and J.S. White. *Development of the stream condition index (SCI) for Florida*. Prepared for Florida Department of Environmental Protection, Tallahassee, Florida, 1996.
- [9] Rankin, E.T. Habitat indices in water resource quality assessments. *Biological assessment and criteria: Tools for water resource planning and decision making*. Lewis Publishers, Boca Raton, Florida, 1995.

[10] Department of Environmental Conservation. “Part 703: Surface Water and Groundwater Quality Standards and Groundwater Effluent Limitations.” Department of Environmental Conservation, 2008.

[11] Zanicowski, L., McDonnell, K., Rockwell, R. and Rispoli, F. Temporal and Spatial Variations in Water Quality on New York South Shore Estuary Tributaries: Carmans, Patchogue, and Swan Rivers. Springer, pp. 85-100, 2008.

[12] Robson, B., and Chester, E. Spatial patterns of invertebrate species richness in a river: the relationship between riffles and microhabitats. *Australian Journal of Ecology*, 24, 599–607, 1999.

Acknowledgements

This work was conducted at Brookhaven National Laboratory and supported by the U.S. Department of Energy, Office of Science, and in part by the Foundation for Ecological Research in the Northeast. This project could not have been accomplished without access to the Carmans River provided by Suffolk County Parks. Additionally, our team also thanks the Office of Educational Programs and the Science Undergraduate Laboratory Internship program for hosting our research and for all of their hard work in creating, organizing, and funding this experience. We would also like to thank Nyesha Smith for all of her assistance in data collection and sampling. Our sincere gratitude goes to our mentor, Timothy Green, PhD., for providing us with such a positive research experience, his guidance, and direction.

Tables and Figures

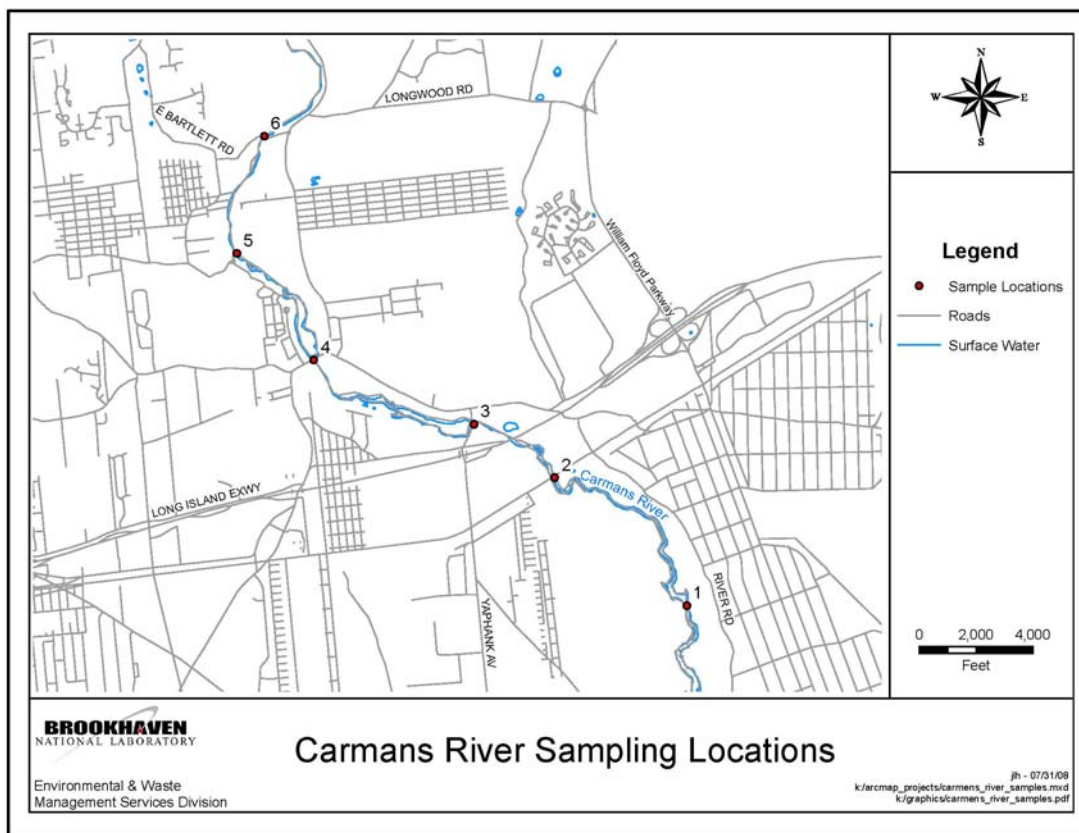


Figure 1 Monitoring locations on the Carmans River.

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

Table 2 Averages for temperature, conductivity, dissolved oxygen, and pH collected for each location in 2008 using the YSI 650 MDS water quality meter.

Site	Location	Temperature:	Conductivity:	DO:	pH:	Velocity
1	C-gate Dam	18.9	186.1	10.6	6.6	1.13
2	Train Tressle	21.7	161.8	9.3	6.9	1.77
3	Lower Lake Dam	24.1	152.8	8.9	7.1	1.21
4	Upper Lake Dam	24.9	154.2	9.7	7.3	1.61
5	Warbler Woods	17.5	149.8	8.6	7.2	0.66
6	East Bartlet	19.5	173.8	6.9	7.2	0.91

Table 3 Averages for temperature, conductivity, dissolved oxygen, and pH collected for each location using the YSI 650 MDS water quality meter for 2009 data.

Site	Location	Temperature:	Conductivity:	DO:	pH:	Velocity:
1	C-gate Dam	16.5	180.3	15.0	6.3	0.7
2	Train Tressle	19.0	161.6	14.2	6.5	2.0
3	Lower Lake Dam	21.8	149.2	14.5	6.9	1.3
4	Upper Lake Dam	21.0	150.4	14.9	6.8	1.7
5	Warbler Woods	14.5	157.6	15.3	6.6	0.7
6	East Bartlet	16.2	186.7	13.9	6.5	0.8

Table 4 Average velocity by habitat for 2008 and 2009 data.

Habitat	Velocity 2008	Velocity 2009
Riffle	2.34	2.41
Run	1.17	1.21
Pool	0.41	0.27

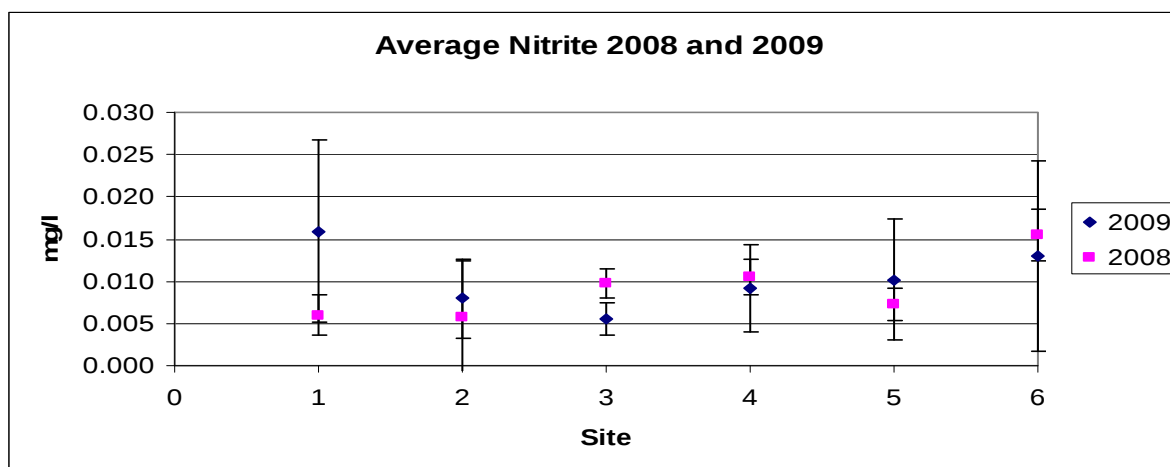


Figure 2 average nitrite levels with standard deviation for each of the six locations from the results of the water analysis using the HACH kit from 2008 and 2009.

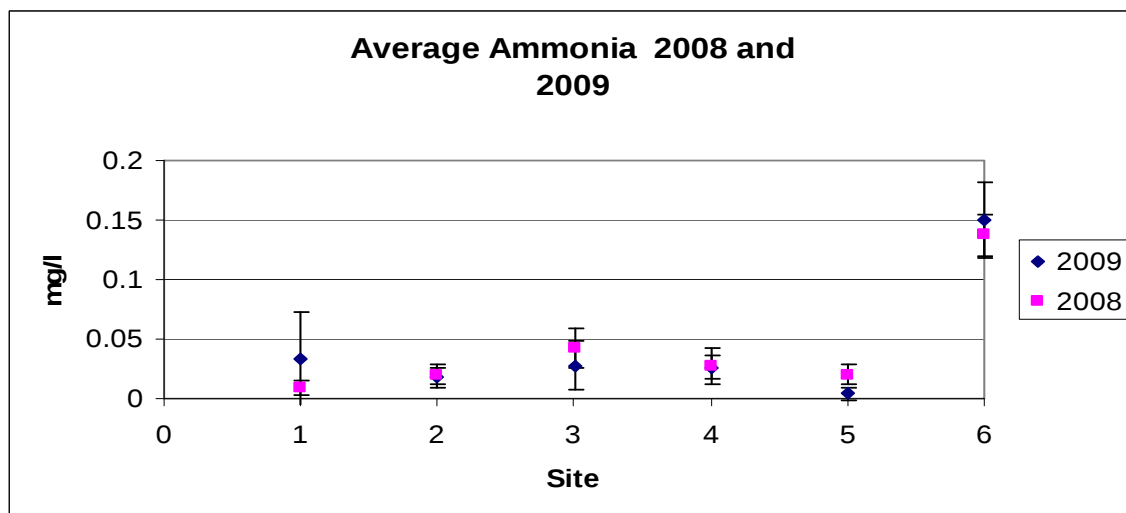


Figure 3 average nitrogen levels with standard deviation for each of the six locations from the results of the water analysis using the HACH kit from 2008 and 2009 collections.

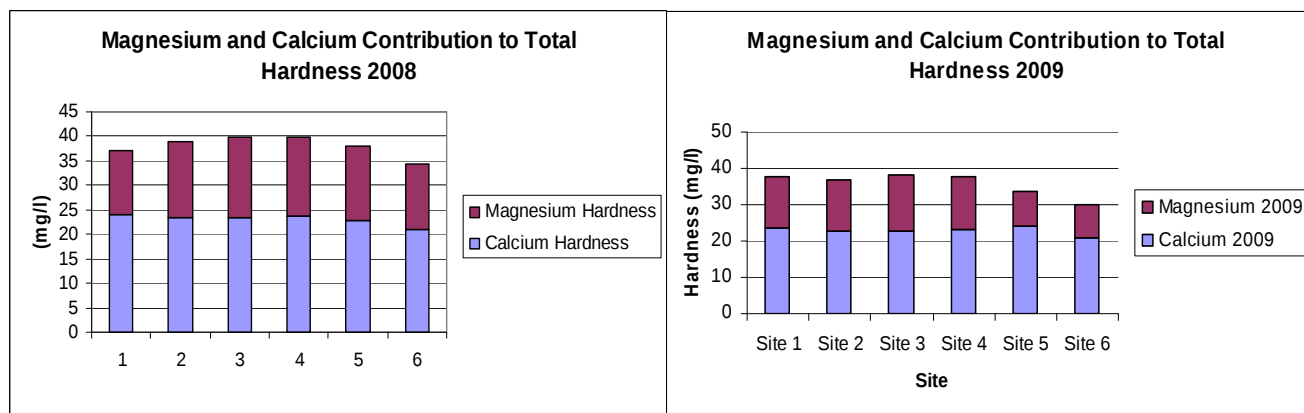


Figure 4 shows the average magnesium hardness and average calcium hardness at each site for 2008 and 2009. Together these equal the total hardness. The values for each water sample were determined using the HACH kit digital titrator.

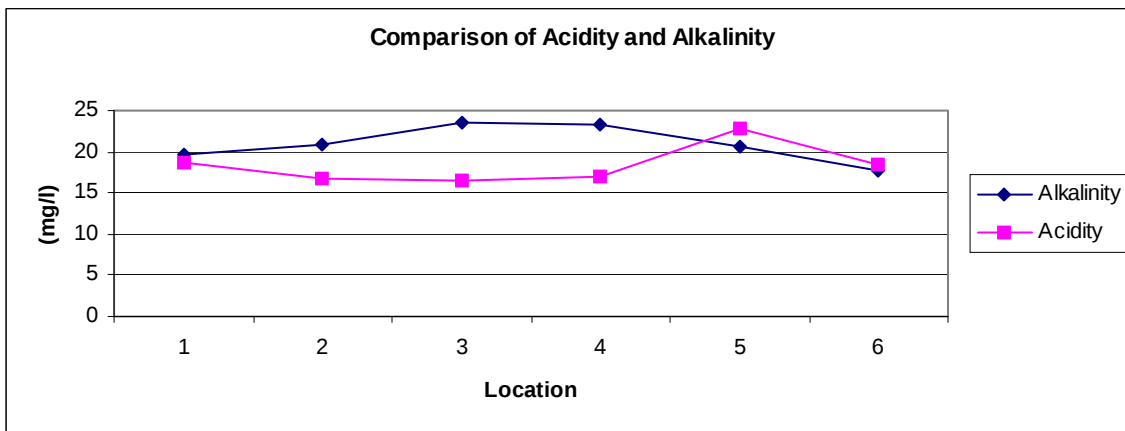


Figure 5 comparison of the alkalinity and acidity for water samples taken at each of the six locations along the Carmans River in 2008. The values for each water sample were determined using the HACH kit digital titrator.

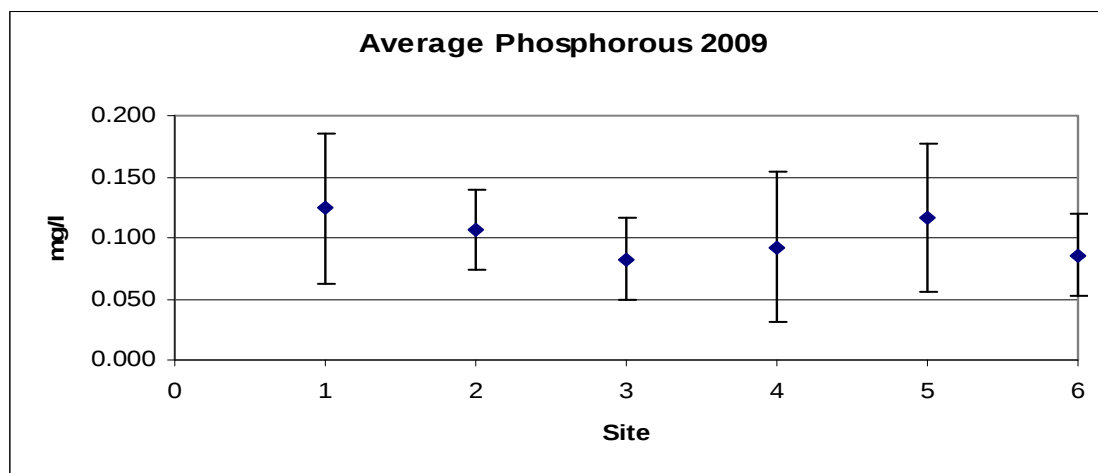


Figure 6. Average phosphorous concentration at each site along the Carmans River in 2009. The values for each water sample were determined using the HACH kit colorimeter.

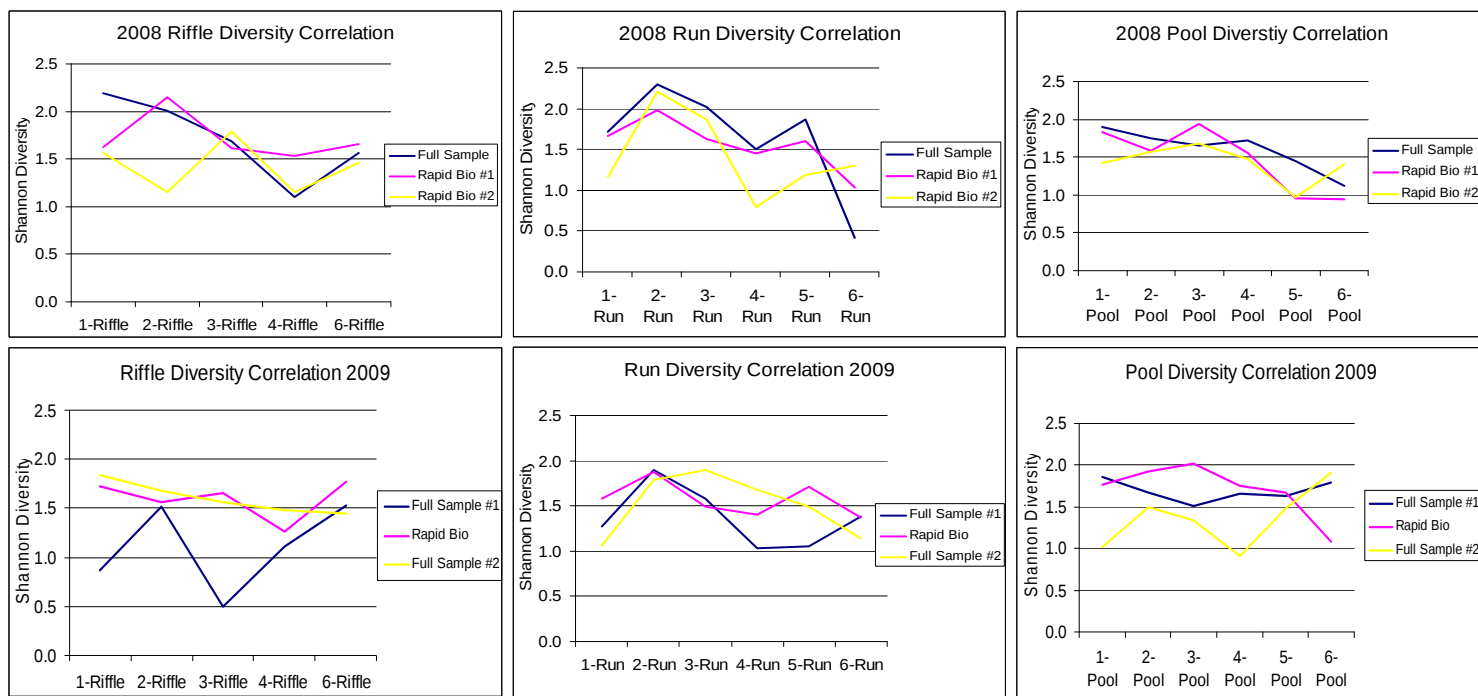


Figure 7. shows the correlation between full sample #1, rapid bio, and full sample # 2 diversity by habitat type for both 2008 and 2009 data collections.

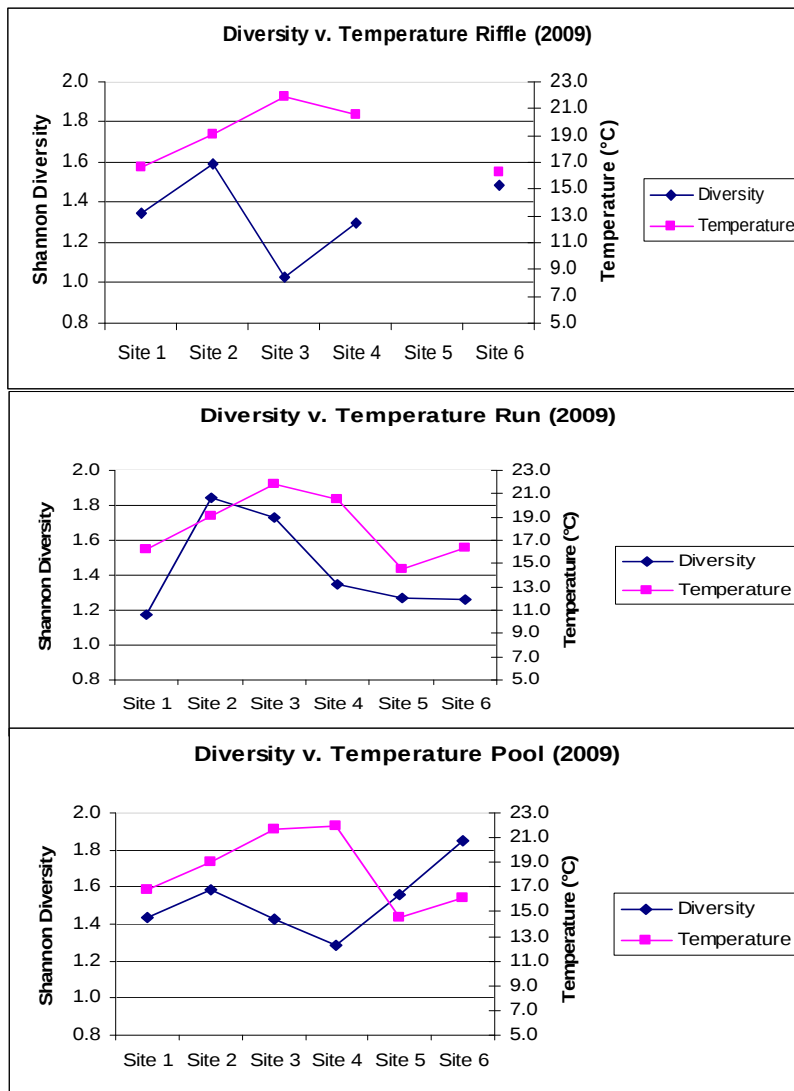


Figure 8. shows the correlation between diversity and temperature by habitat type at each site on the Carmans River from 2009 data.

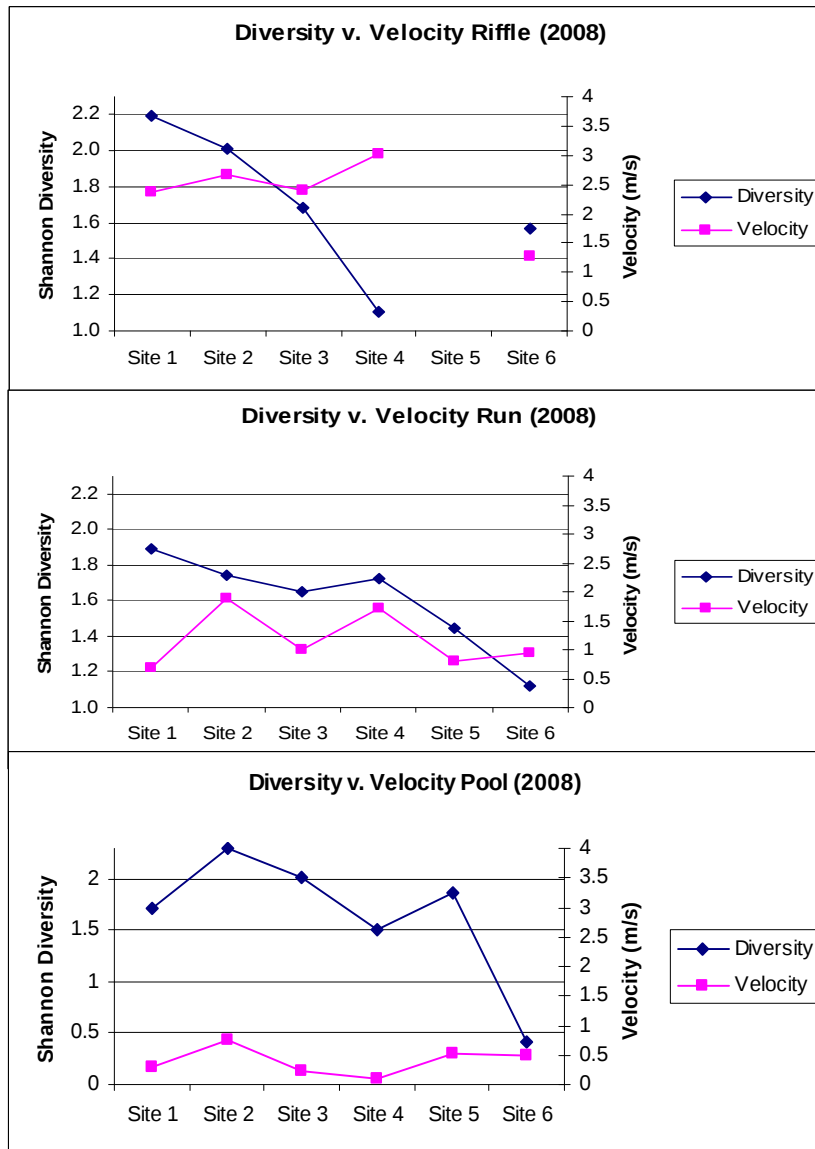


Figure 9. shows the diversity and velocity correlation at each habitat from site collections in 2008 along the Carmans River.

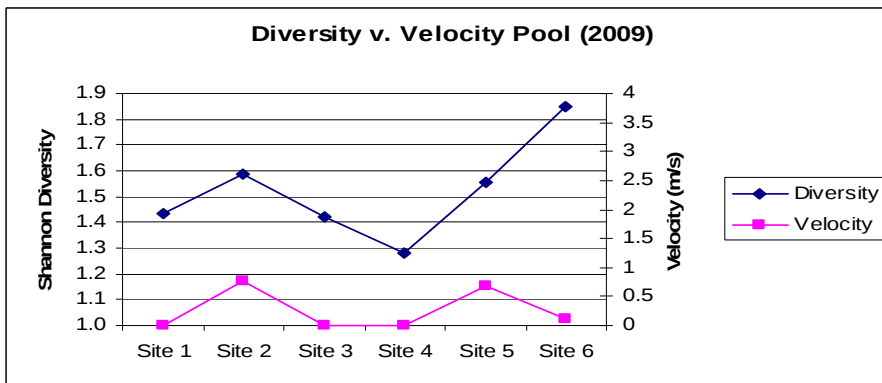
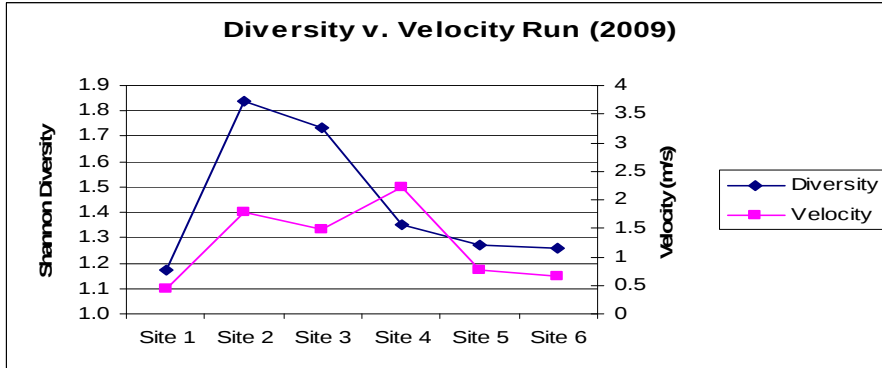
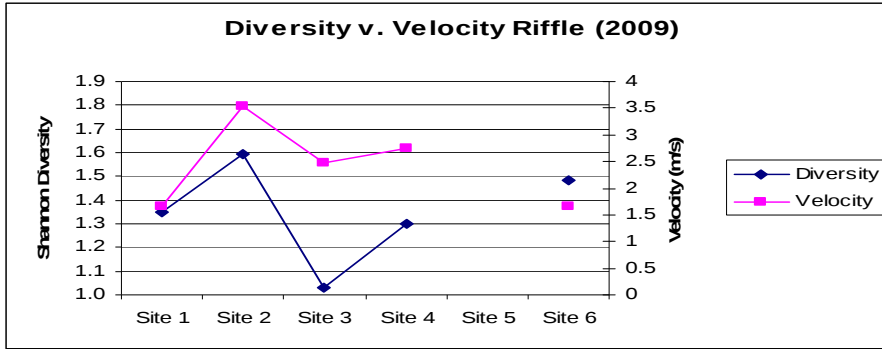


Figure 10. shows the correlation between diversity and velocity at each habitat from the site collections from 2009.