Regional Watershed Monitoring Program: Benthic Macroinvertebrate Summary 2001-2008




Watershed Monitoring and Reporting Section
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TORONTO AND REGION Conservation for The Living City

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Table of Contents

page

List of Tables

List of Figures

Appendices

1. Introduction

Benthic macroinvertebrates (BMI) are organisms that inhabit the bottom of watercourses for at least a portion of their lives. BMI include worms, crustaceans, molluscs and the various life stages of insects (Figure 1). These organisms are sensitive to disturbances in their environment, and a variety of analytical methods have been developed to use these organisms as biological indicators of ecosystem condition or "health" (e.g. Resh and McElravy 1993, Carter and Resh 2001, Jones *et al*. 2005).

Figure 1. Examples of BMI

Bioassessment methods use living organisms to provide insight into environmental conditions. BMI are ideal for use in bioassessment for a number of reasons: they are sedentary and therefore are constantly exposed to the effects of pollution; they are reasonably long-lived (approximately 1-3 years) so the effects of environmental stressors can be time-integrated; and they occur in high diversity, so many different species can potentially react to many different types of impacts. The BMI community is strongly affected by its environment, including sediment composition and quality, water quality, and hydrological factors that influence the physical habitat. Because the BMI community is dependent on its surroundings, it serves as a biological indicator that reflects the overall condition of the aquatic environment. BMI assemblages are perhaps the most widely studied aspects of urban stream ecosystems (Walsh *et al*. 2005). BMI biomonitoring can be used as a tool to examine changes in biological health and water quality of water bodies over time. Traditional chemical evaluations of water quality have been largely inadequate because pollution from chemical non-point sources (e.g. stormwater runoff) may be transient and unpredictable (Barbour *et al*. 1996).

BMI biomonitoring has been part of the Toronto and Region Conservation Authority's (TRCA) Regional Watershed Monitoring Program (RWMP) since 2001. Samples are collected annually at a fixed number of stations (150) across the TRCA watersheds (Figure 2). Supplementary to the fixed sites, additional sites may be sampled in any given year as required for special projects. Supporting environmental data such as stream width, substrate grain size, and the concentration of several chemical analytes (e.g. pH, conductivity) are also collected, in order to distinguish the effects of natural environmental variability from changes due to anthropogenic factors (e.g. urban development). The objective of the TRCA's BMI biomonitoring program is to provide an indication of the biological health of the watersheds.

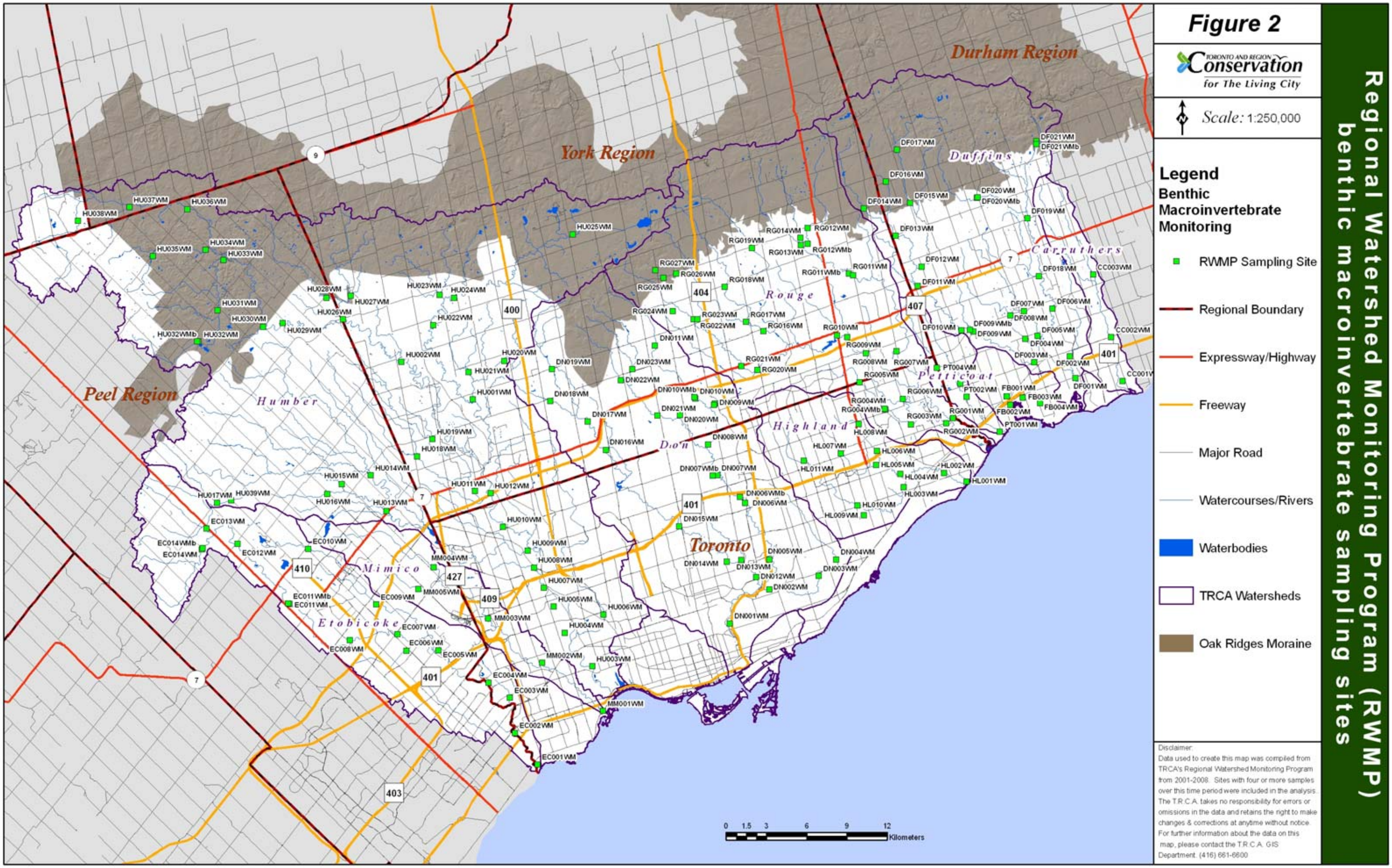


Figure 2
Toronto and Region Conservation for The Living City
Scale: 1:250,000
Regional Watershed Monitoring Program (RWMP) benthic macroinvertebrate sampling sites
Legend
Benthic Macroinvertebrate Monitoring
RWMP Sampling Site
Regional Boundary
Expressway/Highway
Freeway
Major Road
Watercourses/Rivers
Waterbodies
TRCA Watersheds
Oak Ridges Moraine
Durham Region
York Region
Peel Region
Toronto
Humber
Don
Rouge
Highland
Petticoat
Duffins
Carruthers
Mimico
Etobicoke
0 1.5 3 6 9 12 Kilometers
Disclaimer:
Data used to create this map was compiled from TRCA's Regional Watershed Monitoring Program from 2001-2008. Sites with four or more samples over this time period were included in the analysis. The T.R.C.A. takes no responsibility for errors or omissions in the data and retains the right to make changes & corrections at anytime without notice. For further information about the data on this map, please contact the T.R.C.A. GIS Department. (416) 661-6600

This report summarizes the BMI biomonitoring results from 2001-2008. The data were analyzed regionally (i.e. across the TRCA jurisdiction as a whole) and by watershed. The data were analyzed using a combination of indices and multivariate analyses. In addition, the relationship between the BMI data and select habitat and land-use variables is examined. Trend analysis over the 2002-2008 time period is conducted but comparisons with other historical data sets (i.e. not collected by the RWMP) have not been carried out. The three main study objectives were:

1. To characterize the BMI taxonomic composition in each of the ten watersheds within TRCA's jurisdiction;
2. To look for spatial/temporal trends in the BMI community composition and to determine if these trends be explained by land-use, habitat or other factors;
3. To characterize the biological "health" across the jurisdiction.

2. Methods

2.1 Field Collection and Laboratory Procedures

Sampling stations have been established according to the Ontario Stream Assessment Protocol (OSAP) (Stanfield *et al*. 2001). Sampling sites represent at least one riffle-pool sequence, are at least 40 m long and begin and end at a crossover point (Stanfield *et al*. 2001). During the summer months, sampling at each station is carried out using the traveling-kick-and-sweep method (Figure 3) along a number of transects. Each sample is collected using a 500 micron mesh D-net, with the samples from all transects combined into a single composite sample. Samples (BMI and debris) are preserved in the field using buffered formalin and processed in the laboratory. After 48 hours in formalin, the samples are transferred to ethanol for long-term preservation. Samples were identified to the lowest practical level (LPL) which was usually genus.

Figure 3. Collecting BMI using the travelling kick and sweep method

Samples from 2001 to 2003 were identified by contract taxonomists and the entire sample was processed and identified. The 2004 to 2008 samples were identified by TRCA entomology technicians. Rather than identifying the whole sample, standardized random sub-sampling was carried out and a minimum of 100 macroinvertebrate individuals were counted (e.g. Jones *et al*. 2005).

2.2 Data Analysis

Although the BMI data were identified to the LPL level, only family level identifications were used for the data analysis due to differences in the taxonomy over the years. For example, the family Chironomidae was identified to species by some taxonomists but only to the family level by others. Five groups of organisms were not identified to the family level: Oligochaeta (subclass), Acari (subclass), Ostracoda (class), Nemata (Phylum) and Tricladida (Order). Although not identified to the family level, these five groups were treated as families for the data analysis.

For the first three years of sampling, the whole sample was identified but for the remaining years only a 100+ subsample was identified. Because taxa richness inherently increases with the size of the sample (i.e. rarefaction; e.g. Sanders 1968, Soetaert and Heip 1990), the whole samples were reduced to 100+ counts using a virtual Merchant box Excel macro (Walsh 1997). The 100+ counts were then converted to percentages. Prior to analysis, all stations with less than 90 organisms were removed from the data set.

Data analysis was conducted using two statistics programs: JMP 8.0 (SAS Institute, Carrey, North Carolina) and Excel 2007 (Microsoft Corporation, Redmond, Washington). Samples are listed as their site name (watershed code plus site number) and the year the sample was taken (e.g. HU032WM-06 represents site 32 in the Humber River watershed taken in 2006).

2.2.1 Indices

The most common way to describe BMI communities is through the use of indices. An index is a simple calculated term or enumeration representing some aspect of biological assemblage or function. An index is characteristic of the biota and changes in a predictable way to perturbation. Indices provide summation statistics for individual groups which allow for insight into biological properties such as pollution and disturbance tolerance and taxonomic diversity (Ourso and Frenzel 2003).

BMI community composition was summarized using ten indices (Table 1) that have been shown to be sensitive to environmental conditions. A combination of richness indices, compositional indices, a diversity measure, and one weighted taxa-tolerance index (Hilsenhoff's modified Family Biotic Index [FBI]) were used. A description of each index is provided in Appendix A.

To help decipher how sites were performing in comparison to each other, an average value for each index was calculated for the jurisdiction. The results for each site were compared to the jurisdictional "average" which was defined as the average index value bounded by (±) one standard deviation. Sites outside this range were defined as "above normal" (greater than average plus one standard deviation) and "below normal" (less than average minus one standard deviation).

Table 1. Ten indices used to summarize the taxonomic composition of the BMI community and their predicted responses to perturbation

Index	***Response to Perturbation***	***Reference(s)***
	Richness Measures	
Family richness	Decrease (↓)	Bazinet *et al*. 2010, Garie and MacIntosh 1986, Kerans and Karr 1994, Morse *et al*. 2003, Stepenuck *et al*. 2002, Voelz *et al*. 2005, Walsh *et al*. 2001
EPT family richness	Decrease (↓)	Barbour *et al*. 1996, Bazinet *et al*. 2010, Garie and MacIntosh 1986, Morse *et al*. 2003, Stepenuck *et al*. 2002, Voelz *et al*. 2005, Walsh *et al*. 2001
Trichoptera family richness	Decrease (↓)	Barbour *et al*. 1999, Bazinet *et al*. 2010
	Compositional Measures	
% EPT	Decrease (↓)	Bazinet *et al*. 2010, Duda *et al*. 1982, Hachmoller *et al*. 1991, Jones and Clark 1987, Morse *et al*. 2003, Pitt and Bozeman 1982, Pratt *et al*. 1981; Stepenuck *et al*. 2002, Voelz *et al*. 2005, Walsh *et al*. 2001
% Chironomidae	Increase (↑)	Duda *et al*. 1982, Garie and MacIntosh 1986, Maxted 1996, Pratt *et al*. 1981, Whiting and Clifford 1983
% Oligochaeta	Increase (↑)	Barbour *et al*. 1996, Bazinet *et al*. 2010, Duda *et al*. 1982, Pratt *et al*. 1981, Kerans and Karr 1994, Pitt and Bozeman 1982, Voelz *et al*. 2005
% Dominant Family	Increase (↑)	Barbour *et al*. 1996; Barbour *et al*. 1999
% Gastropoda	Variable	Barbour *et al*. 1996
	Diversity Measure	
Simpson's Diversity	Decrease (↓)	Barbour *et al*. 1992, Benke *et al*. 1981, Hachmoller *et al*. 1991, Kerans and Karr 1994, Klein 1979, Pratt *et al*. 1981, Shutes 1984, Stepenuck *et al*. 2002, Whiting and Clifford 1983
	Biotic Index	
Family Biotic Index[1] (Hilsenhoff 1988; Bode *et al*. 2002)	Increase (↑)	Bazinet *et al*. 2010, Stepenuck *et al*. 2002, Voelz *et al*. 2005

[1] Families and associated tolerance values used to calculate the FBI are provided in Appendix A.
Table adapted from Barbour *et al*. (1999) and Bazinet *et al*. (2010)

The Reference Condition Approach (e.g. Bailey *et al*. 2004) was used to compare several indices (family richness, % EPT, % Chironomidae, % Oligochaeta, FBI) to published values for least-disturbed reference sites. The BMI community of a potentially stressed ecosystem is compared with that of unstressed reference sites that have similar environmental conditions. This model defines the range of biological communities that should be found at a site if the site is not affected by human activities. Jones (2009) established "normal" ranges for third to fifth order streams in southwestern Ontario. The normal range was based on the 25th and 75th percentile geographic-information-system (GIS) based reference sites which had less than 33% agricultural land use, less than 1% settled/developed land use, a road density of less than 1.0 km/km^2 and greater than 18% forested area in the upstream catchment. Although Jones' reference sites are not in the same geographic area (e.g. southwestern Ontario is predominantly agricultural) and some RWMP sites are second (23%) and sixth (3%) ordered steams; Jones' reference sites provide the best baseline data available for comparison at this time.

2.2.2 Temporal Trends

Temporal trends of index values were analyzed using the Mann-Kendal non-parametric test. The data values are evaluated as an ordered time series. The initial value of the Mann-Kendall statistic, S, is assumed to be zero (*e.g.*, no trend). If a value from a later time period is higher than a value from an earlier time period, S is incremented by one. On the other hand, if the value from a later time period is lower than a value sampled earlier, S is decremented by one. The net result of all such increments and decrements yields the final value of S. For example, a very high positive value of S is an indicator of an increasing trend, and a very low negative value indicates a decreasing trend. An alpha level (α) of 0.1 was used to determine if temporal trends were significant. If a test of significance gives a p-value lower than the α-level, the null hypothesis is rejected. For example, if the p-value for a Mann-Kendall test is 0.03, the p-value is less than the significance level (α=0.1), and the observed trend is statistically significant we infer that a trend is present. Sites which were sampled a minimum of 6 times from 2002-2008 (N=133) were used for the analysis. Data from 2001 was excluded from the trend analysis because some of the data appeared to be outliers, most likely due to differences in taxonomists.

2.2.3 Regression Analysis

The relationships between the environmental variables (Appendix B) and the BMI community indices were examined using regression analysis. Multiple linear regression was used to model each index using multiple predictors. BMI indices (2002) were regressed with 2002 land-use data and 2001-2003 habitat data (habitat data is collected on a 3-year rotation with fish data). Regression analysis provided a tool to statistically determine if any indices varied as a function of the environmental variables. The coefficient of determination (R^2) and F-value are used to describe the relationships. R^2 is the proportion of variability in a data set that is accounted for by the statistical model. It is a measure of association which represents the percent of the variance in the response variables (e.g. biological indices) that can be explained by the independent variable (e.g. land-use). The values vary from 0 (none of the variance is explained) to 1 (all of the variance is explained). The F-value is a test for statistical significance of the regression equation as a whole. It is obtained by dividing the explained variance by the unexplained variance. The F-value can be thought of as a signal to noise ratio whereby as F increases (i.e. more signal, less noise), p decreases.

2.2.4 Multivariate Analysis

Ordination summaries are multivariate techniques. Rather than summarize composition with a single index, or set of indices, as described previously, these approaches consider all taxa present, each on being an attribute of the site it was collected at. Ordinations produce a set of new variables, called ordination axes that represent community composition (Gauch 1982, Kilgour *et al.* 2004). Patterns of similarities and differences amongst the BMI community are summarized into axes which are uncorrelated with each other (see Stanfield and Kilgour 2006 for a more detailed description).

2.2.4.1 Correspondence Analysis

Correspondence analysis (CA) is an ordination technique that can be used to summarize or visualize community structure graphically. Using the relative counts of taxa present, it projects sites onto a set of axes. The closer the sites plot in the resulting coordinate frame, the more similar they are biologically. The 2002 BMI data were used for CA because the land-use data used for Canonical Correspondence Analysis was from 2002 (see Section 2.2.5.2). Frenchman's Bay was not sampled for benthic invertebrates in 2002; therefore, only 9 watersheds were included for analysis. Prior to CA and CCA, raw abundances were transformed using log (X+1) to help normalize the data. Families which did not occur at greater than 10% of the sites were excluded to reduce the influence of rare taxa on ordinations. All CA analyses were performed using the Biplot add-in for Excel (Lipkovich and Smith 2002).

2.2.4.2 Canonical Correspondence Analysis

Canonical correspondence analysis (CCA) is an extension of CA with the added restriction that the ordination axes must be expressed in terms of environmental variables. This constrained technique looks for implicit relationships between the ordination of abundance data and environmental variables. The use of CCA allows patterns which result from the combination of several explanatory variables to be recognized which may not have been clear if each explanatory variable was considered individually. CCA is a direct gradient analysis technique used to examine the association between the benthic invertebrate community composition, habitat and land-use variables.

BMI data from 2002 was analysis to correspond to the 2002 land-use data. Frenchman's Bay was not sampled for benthic invertebrates in 2002; therefore, only 9 watersheds were included for analysis. Prior to analysis, the BMI data were log (X+1) transformed to improve normality and families which did not occur at greater than 10% of the sites were excluded to reduce the influence of rare taxa on ordinations. Correlated environmental variables were left in the CCA matrix as it is possible that even highly correlated variables explain slightly different aspects of community composition (Palmer 1993). Habitat variables (average width, average depth, width/depth ratio, D16, D50, D84, % Pools, % Riffles, % Glides) from 2001-2003 were used as habitat data is collected in conjunction with the fish sampling (3-year rotational basis). The land-use data (% Urban, % Urbanizing, % Rural, % Beach/Bluff, % Forest, % Meadow, % Successional, % Wetland, % L1Cover, % L2Cover, % L3Cover, % L4Cover, Catchment Area (km^2), Road Density, Slope, Stream Order) were derived using a Geographical Information System (GIS) along with orthophotography and terrestrial data collected by TRCA staff. Further explanations of these environmental variables can be found in Appendix B. All CCA analyses were performed using the Biplot add-in for Excel (Lipkovich and Smith 2002).

3. Results and Discussion

3.1 Jurisdictional Analysis

For the jurisdictional investigation, sites with greater than four years of data (1045 samples) were included in the analysis.

3.1.1 Community Composition

3.1.1.1 General

A total of 114 families were identified from 2001-2008 (Appendix A). The most abundant taxa were Oligochaeta, Chironomidae (Diptera) and Baetidae (Ephemeroptera). Thirty-five (35) families were collected at five or fewer sites over the eight-year period (Table 2) and can be considered rare in the TRCA's jurisdiction.

Table 2. Rare BMI families in the TRCA's jurisdiction

Rare Benthic Invertebrate Families				
Belostomatidae	Dryopidae	Libelluidae	Pontoporeiidae	Siphlonuridae
Brachycentridae	Ecnomidae	Molannidae	Potamanthidae	Staphylinidae
Capniidae	Ephemeridae	Phryganeidae	Psychomyiidae	Syrphidae
Carabidae	Goeridae	Planariidae	Ptiliidae	Taeniopterygidae
Chaoboridae	Hydraenidae	Pleidae	Ptychopteridae	Uenoidae
Chrysomellidae	Hydridae	Polymitarcyidae	Pyralidae	Unionidae
Dipseudopsidae	Hydrobiidae	Pomatiopsidae	Sciomyzidae	Valvatidae

3.1.1.2 Index Analysis

A summary of the jurisdictional indices for RWMP sites (N>4 years) are shown in Table 3. Average index values for each site are provided in Appendix A. The results for each index are also mapped in Figures 4 to 13.

Table 3. Jurisdictional index values calculated from 1045 samples collected annually from 148 sites (2001-2008)

Index	Average	Std Dev	Minimum	Maximum
Family Richness	10	3	4	17
# EPT Families	3	2	0	7
# Trichoptera Families	1	1	0	3
% Chironomidae	37	13	3	67
% EPT	19	14	0	66
% Gastropoda	2	2	0	9
% Oligochaeta	13	13	0	77
Dominant Family (%)	49	11	30	86
FBI	6.46	0.77	5.19	9.14
Simpson's Diversity	0.66	0.11	0.22	0.83

Family Richness

Family richness reflects the diversity of the aquatic assemblage and increasing diversity correlates with increasing health of the assemblage. The average number of families across the jurisdiction from 2001-2008 was 10 and the average per individual site ranged from 4 to 17 families across the jurisdiction. Approximately 18% of sites had above normal number of families while 16% had below normal number of families (Figure 4). Higher diversity indicated better watershed health. The maximum number of families at an individual site was 24 in 2006 at RG013WM which is located on the Little Rouge Creek in the upper reaches of the Rouge River. Of the 1045 samples identified, only 13 samples (11 sites) had 20 or more families. The sites were all located in the Humber River, (HU022WM-02, HU023WM-02, HU037WM-05), Rouge River (RG007WM-03, RG013WM-06, RG014WM-06, RG016WM-02) and Duffins Creek (DF004WM-02, DF002WM-04, DF008WM-04, DF008WM-06, DF012WM-02, DF015WM-02). The minimum number of families was two which were found at six stations. These six samples were found in the Don River (DN001WM-07, DN003WM-08, DN004WM-03), Etobicoke Creek (EC003WM-01), Frenchman's Bay (FB004WM-06) and Highland Creek (HL008WM-08).

Number of EPT Families

EPT is the short form for Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). These taxa are generally considered to be sensitive to pollution and high abundance can indicate good environmental conditions. Figure 5 displays the average number of EPT families by site. The jurisdictional average number of EPT families was three for 2001-2008. The jurisdictional average range was 0 to 7 EPT families. Station RG013WM on Little Rouge Creek had the highest number of EPT families at an individual site with 11 EPT families in 2008. Six stations had 10 or more EPT families: DF012WM-02, DF015WM-02, HU030WM-05, HU037WM-05, HU038WM-07, RG013WM-08. Approximately 11% of the total number of samples (119 samples) did not contain any EPT organisms. These sites were located in all ten watersheds sampled. Higher percentages of EPT organisms indicate better watershed health.

Number of Trichoptera Families

Trichoptera (caddisflies) are ubiquitous throughout the TRCA's jurisdiction. Like the other richness measures, increased number of Trichoptera families suggests increased watershed health. The average number of Trichoptera families per site is shown in Figure 6. The jurisdictional average number of Trichoptera families was 1 and the jurisdictional range was 0 to 3 Trichoptera families. The highest number of Trichoptera families found at an individual site was five. There were ten different sites across the region with five different Trichoptera families. All ten sites were located either in the Duffins Creek watershed (DF003WM-02, DF007WM-02, DF008WM-04, DF010WM-02, DF012WM-02, DF015WM-03) or the Humber River watershed (HU002WM-02, HU016WM-02, HU030WM-05, HU038WM-07). Approximately 24% of the samples, representing all ten watersheds, did not have any Trichoptera families. As with the previous richness measures, increased Trichoptera diversity suggests increased watershed health. Although Trichoptera larvae are found in a wide range of aquatic habitats, the greatest diversity occurs in cool running waters (Williams and Feltmate, 1992)

Percent EPT

Similar to the number of EPT families, a high percentage of EPT organisms suggests high quality stream environments. On average, the BMI community was made up of 19% EPT organisms across the jurisdiction. Approximately 16% of the sites were above then normal range and 20% of the sites were below the normal range (Figure 7). The site with the highest EPT composition was DN013WM in 2004 at 93% which was made up of 90% Ephemeroptera (Baetidae) and 3% Trichoptera (Hydropsychidae). Both of these families are considered relatively tolerant to environmental disturbance. DN013WM is located in the Lower Don River watershed in Serena Gundy Park. Approximately 7% (80 samples) were comprised of greater than 50% EPT organisms. Approximately 11% of the samples (119 samples) did not contain any EPT organisms. These sites were located in all ten watersheds sampled.

Percent Chironomidae

The predominance of Chironomidae (midges) generally indicates poor habitat/water quality conditions. The average percentage of Chironomidae is presented in Figure 8. Virtually every sample collected contained Chironomidae. There were only five sites which did not contain any Chironomidae (DN01WM-04, DN015WM-04, EC007WM-05, HU022WM-08, PT003WM-04). The jurisdictional average percentage of Chironomidae was 37%. The maximum percentage of Chironomidae was 98% at site MM005WM-01 located north of Derry Road and west of Airport Road in an agricultural field in the Mimico Creek watershed. Approximately 6% of the samples (62 samples) were comprised mainly of Chironomidae (75% or greater).

Percent Oligochaeta

Oligochaeta (aquatic worms) are considered tolerant organisms. Therefore, if found in relatively high numbers, it may suggest poor habitat/water quality conditions. The average percentage of Oligochaeta per site is presented in Figure 9. The jurisdictional average percentage of Oligochaeta was 13% from 2001-2008. The maximum percentage of Oligochaeta was 98% at DN001WM-08 located at the mouth of the Don River. Only 5% of the samples (56 samples) had greater than 50% Oligochaeta and only 1% of the samples (15 samples) had greater than 75% Oligochaeta. Approximately 15% of the samples (163 samples) did not have Oligochaeta. Low densities of Oligochaeta do not necessarily indicate clean water conditions. Oligochaeta are typically associated with finer sediments which may not be present at all sites and sediments could be severely polluted to the point where even Oligochaeta cannot survive (Ciborowski 2003).

Percent Dominant Family

A high percentage of a single group indicates that the habitat (including water quality conditions) is favouring the reproduction of a particular group. The dominance of any one group at a site represents a concern, particularly if dominated by a group associated with poor stream quality. On average, a single family comprised 49% of the BMI community on a jurisdictional basis. Approximately 9% of the samples (96 samples) were made up of one family comprising greater than 75% of the community. This suggests that the site conditions are favouring the reproduction of a particular group rather than a mix of groups. Site MM005WM-01 (in the upper reaches of Mimico Creek) had the highest percent dominant family with Chironomidae making up greater than 98% of the community. Chironomidae are considered tolerant to pollution. Most samples were well diversified with 61% of the samples (642 samples) having a single family comprising less than 50% of the community (Figure 10).

Percent Gastropoda

Although snails are generally present at most stream sites in southern Ontario, they are not found in large numbers expect when the water velocity is very slow and there is heave enrichment (i.e. organics). The percentage of Gastropoda per site is presented in Figure 11. In high numbers, Gastropoda can represent habitats with organic enrichment and low oxygen levels. Gastropoda were collected from less than half (45%) of the 1045 samples. The jurisdictional average percentage of Gastropoda was 2% of the BMI community. The site with the highest percentage of Gastropoda was HU032WM-06 (upper reaches of Humber River) where the community was comprised of 43% Gastropoda. Only 1% (9 samples) of the samples were comprised of more than 25% Gastropoda. These samples were collected in the Duffins Creek (DF011WM-02), Etobicoke Creek (EC006WM-02, EC007WM-01, EC012WM-01), Highland Creek (HL007WM-02), Humber River (HU032WM-06), Mimico Creek (MM003WM-02) and Rouge River (RG017WM-06). This metric does not properly describe the BMI community because of the low number of sites at which Gastropoda were present.

Simpson’s Diversity

The Simpson’s Diversity Index is related to the proportion of total organisms contributed by each taxon. Diversity is low when the benthic community is dominated by a few taxa, and higher when the number of organisms is more evenly distributed across numerous taxa. The index ranges from 0 which represents no diversity to 1 which represents infinite diversity. The average Simpson’s Diversity score across the region was 0.66. Keeping in mind that Simpson’s Diversity values close to one imply higher diversity (hence higher ecological health), this suggests that the general diversity of the region is fairly high. Approximately 12% of sites had an average Simpson’s Diversity score above the jurisdictional average while 16% of sites had scores below the average (Figure 12). The lowest Simpson’s Diversity score at an individual sampling site was 0.04 at site MM005WM in 2001. The BMI community at that site was comprised of only three groups: Oligochaeta (1%), Chironomidae (98%) and Coenagrionidae (1%). All three groups are quite tolerant to environmental disturbance. Individual sites with the highest diversity were HU022WM in 2002 and HU037WM (both located in the upper reaches of the Humber River) in 2005 with a score of 0.90. Over 63% (655 samples) of the 1045 samples had a Simpson’s Diversity value greater than the jurisdictional average of 0.66.

Family Biotic Index

The FBI is a weighted index designed to reflect the nutrient status of streams. Values range from 1 to 10 and increase as water quality decreases. FBI values are presented in Figure 13. The jurisdictional average FBI value was 6.46 which is rated “fairly poor” suggesting that substantial organic pollution is likely. The best FBI value (i.e. lowest) was 5.19 which has a rating of fair and the worst FBI value (i.e. highest) was 9.14 with a rating of very poor. Site HU037WM had the best individual FBI score of 4.26 in 2005. An FBI value of 4.26 has a rating of “good” and suggests that only some organic pollution is probable. Based on average FBI scores, the 10 best sites were in the Duffins Creek (DF010WM, DF003WM, DF012WM, DF015WM), Humber River (HU029WM, HU030WM, HU038WM) and Rouge River (RG012WM, RG013WM, RG026WM) watersheds. Of the 10 worst sites were, 5 were located in the Don River watershed (DN001WM, DN004WM, DN017WM, DN019WM, DN020WM), 2 in the Highland Creek watershed (HL006WM, HL009WM), and 1 in the Humber River (HU006WM), Etobicoke Creek (EC003WM), and Mimico Creek (MM001WM) watersheds. Of the 1045 samples identified over the 8 years of monitoring, only 2% (23 samples) had FBI ratings of “good” or better (<5.00). These samples were collected from the Duffins Creek, Humber River, Rouge River and Petticoat Creek watersheds. The highest (i.e. worst) individual FBI value was 9.9 at the mouth of the Don River (DN001WM) in 2008. Site DN001WM is located at the mouth of the Don River. The score of 9.9 has an associated rating of “very poor” and suggests that severe organic pollution is likely. Approximately 19% of the samples (195 samples), with samples located in all 10 watersheds, had FBI scores of 7.26 of greater suggesting that severe organic pollution was likely.

Comparison with Published Index Values for Reference Sites in Southwestern Ontario

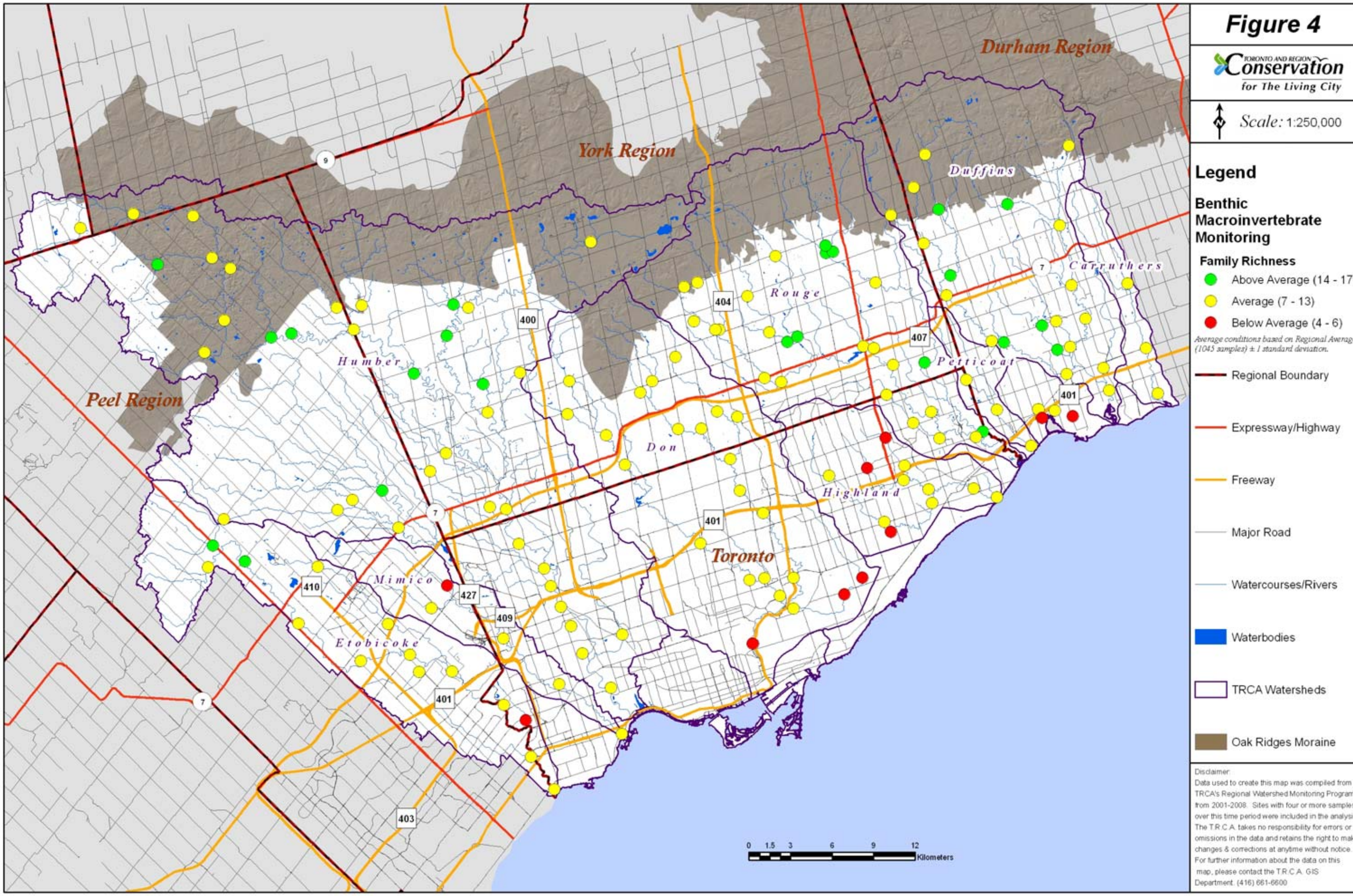
Jones (2009) established normal ranges for several indices for reference BMI in southwestern Ontario using reference sites. Five of the indices were calculated for this report: family richness, % EPT, % Chironomidae, % Oligochaeta (equivalent to % non-hirudinean Clitellata) and FBI. On a jurisdictional basis, % Chironomidae and % EPT were within the normal range. % Oligochaeta and FBI were above (i.e. worse) than the established normal range. The normal range for % Oligochaeta is between 1.1 and 8.7% while the TRCA jurisdictional average was 13%. The normal range for FBI is between 5.0 and 6.3 while the TRCA jurisdictional average was 6.4. This is slightly above the normal range (within the 95% confidence interval for the 75th percentile). The TRCA jurisdictional average for family richness was 10 families which was below the southwestern Ontario reference site normal range of 13.2 to 17.7. These results suggest that the health of the TRCA streams is below that of the southwestern Ontario *reference* sites. That being said, two of the five indices were within the normal range including the % EPT which are considered sensitive species and the TRCA jurisdictional FBI value which was very close to the normal range.

Summary

The index values suggest that most of the sites sampled fall within the normal range of variation across the TRCA jurisdiction. With the exception of the % Gastropoda index, the majority of the indices used were able to discern the healthy versus unhealthy sites. This may be because Gastropoda were found at a relatively low number of sites (<50%) and in very low proportions (jurisdictional average = 2% of total community). A different index should be considered for future analysis.

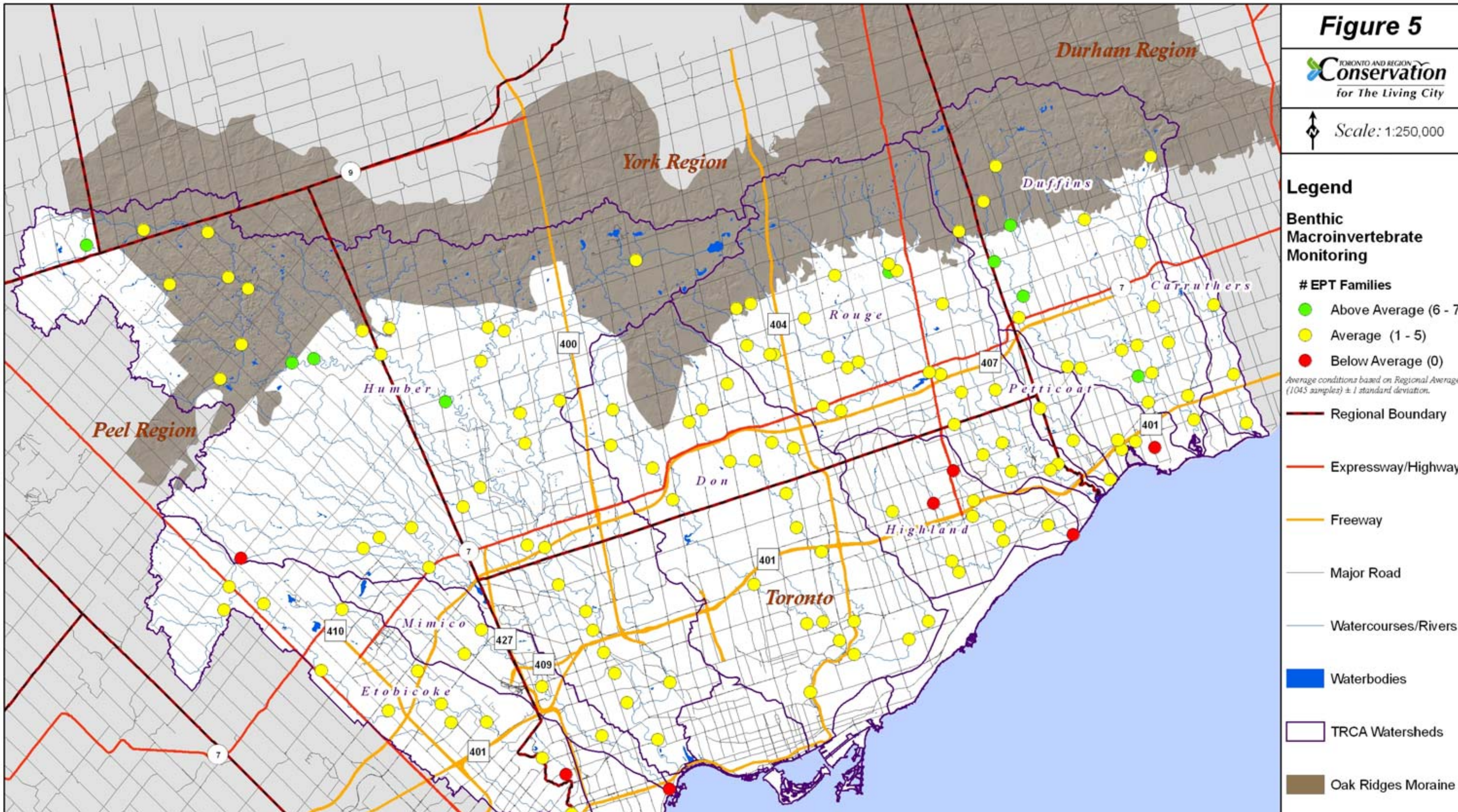
Several sites stand out as either exceptionally healthy or unhealthy. The healthy sites are all located in the Duffins Creek (DF012WM, DF013WM, DF015WM), Rouge River (RG012bWM, RG013WM) and Humber River watersheds (HU002WM, HU029WM, HU030WM) while the unhealthy sites are located in Mimico Creek (MM001WM), Don River (DN004WM, DN022WM) and Highland Creek (HL007WM, HL008WM). Generally, the healthy sites are coldwater (receive input from groundwater) streams in the upper reaches of watersheds with low levels of urbanization (<10%) and relatively high levels of forest (12-40%) in the upstream catchment. The unhealthy streams have high levels of urbanization (63-100%) and low levels of forest cover (<2%). These sites also tend to have anthropogenic modifications such as concrete lined channels or gabion caging.

Figure 4



Average number of benthic macroinvertebrate families by site (2001-2008)

Figure 5



Disclaimer:
Data used to create this map was compiled from TRCA's Regional Watershed Monitoring Program from 2001-2008. Sites with four or more samples over this time period were included in the analysis. The T.R.C.A. takes no responsibility for errors or omissions in the data and retains the right to make changes & corrections at anytime without notice. For further information about the data on this map, please contact the T.R.C.A. GIS Department. (416) 661-6600

Average number of EPT families by site (2001-2008)

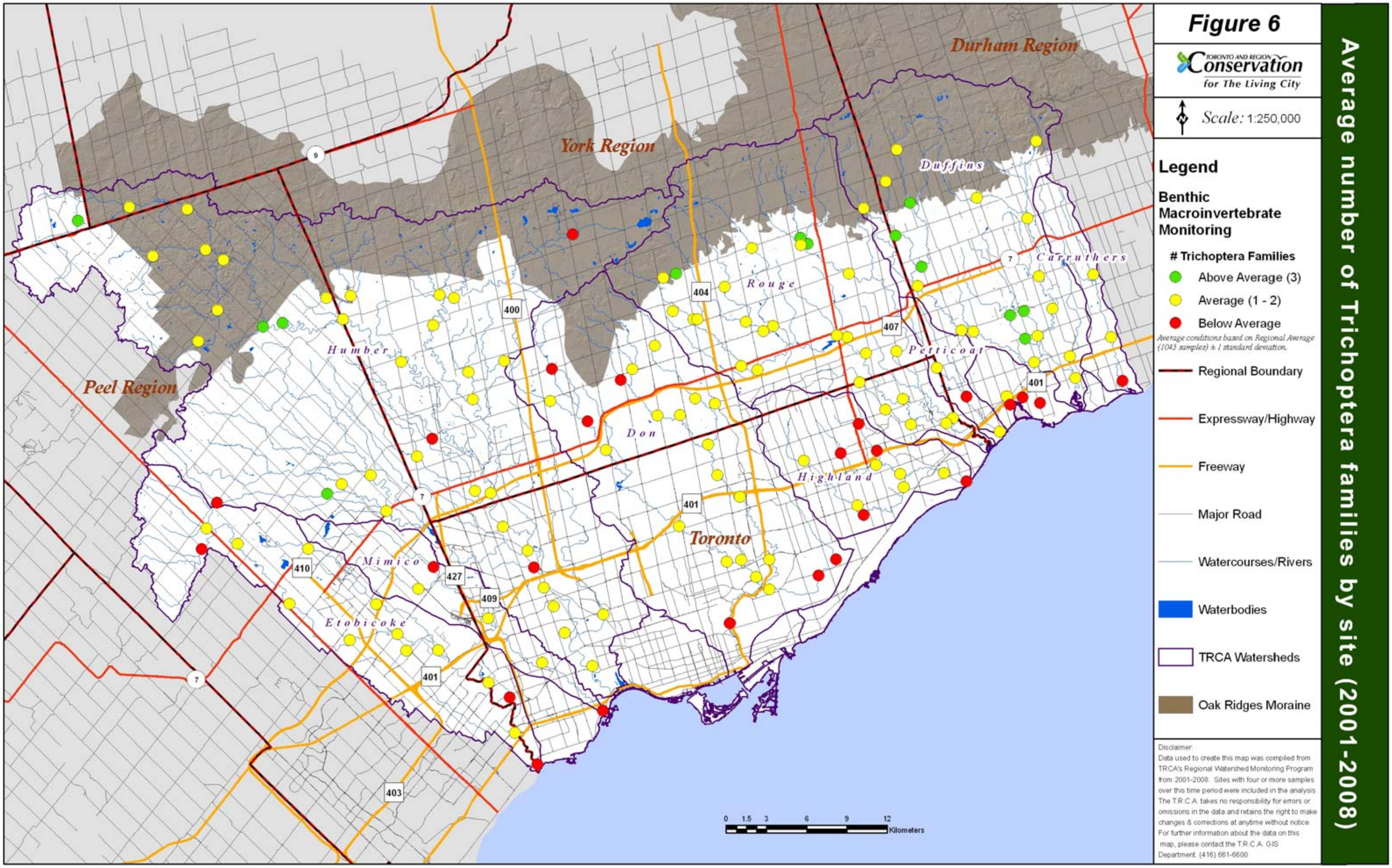
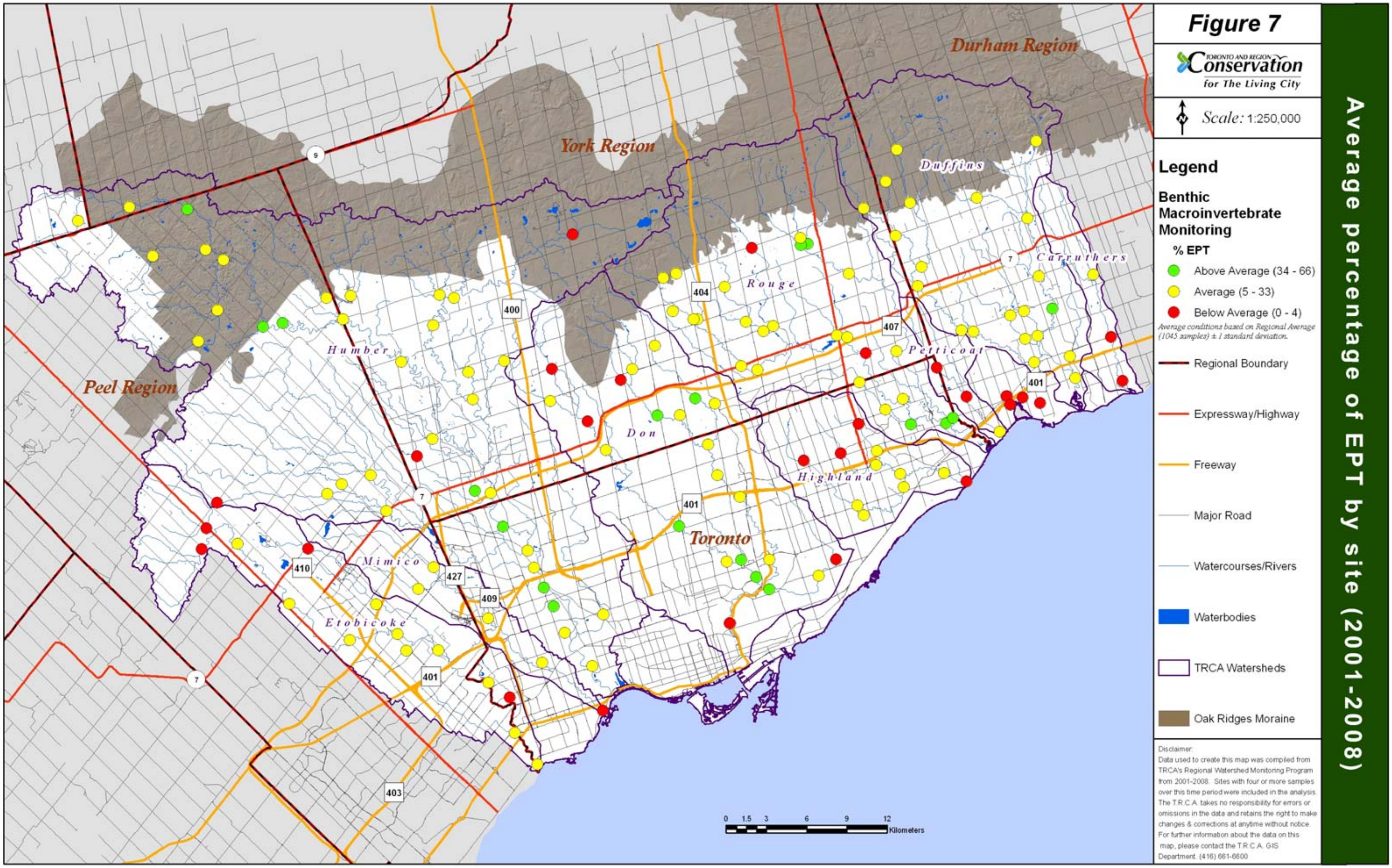


Figure 6
Toronto and Region Conservation for The Living City
Scale: 1:250,000
Average number of Trichoptera families by site (2001-2008)
Legend
Benthic Macroinvertebrate Monitoring
Trichoptera Families
Above Average (3)
Average (1 - 2)
Below Average
Average conditions based on Regional Average (1045 samples) ± 1 standard deviation.
Regional Boundary
Expressway/Highway
Freeway
Major Road
Watercourses/Rivers
Waterbodies
TRCA Watersheds
Oak Ridges Moraine
Disclaimer:
Data used to create this map was compiled from TRCA's Regional Watershed Monitoring Program from 2001-2008. Sites with four or more samples over this time period were included in the analysis. The T.R.C.A. takes no responsibility for errors or omissions in the data and retains the right to make changes & corrections at anytime without notice. For further information about the data on this map, please contact the T.R.C.A. GIS Department. (416) 661-6600
Durham Region
York Region
Peel Region
Toronto
Duffins
Carruthers
Rouge
Petticoat
Humber
Don
Highland
Mimico
Etobicoke
0 1.5 3 6 9 12 Kilometers



Average percentage of EPT by site (2001-2008)

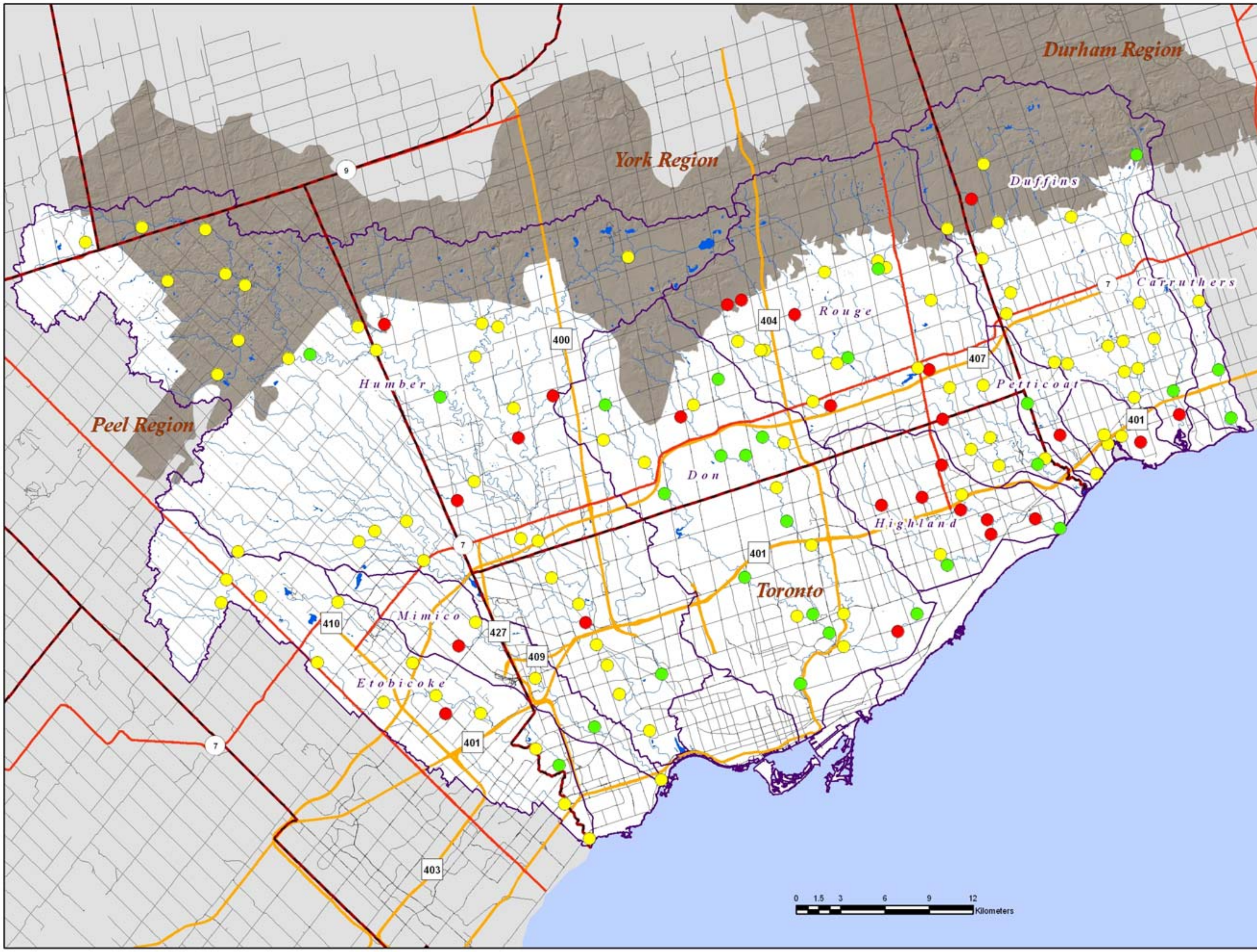


Figure 8

TORONTO AND REGION Conservation for The Living City

Scale: 1:250,000

Legend

Benthic Macroinvertebrate Monitoring

% Chironomidae

- Above Average (3 - 23)
- Average (24 - 50)
- Below Average (51 - 67)

Average conditions based on Regional Average (1045 samples) ± 1 standard deviation.

- Regional Boundary
- Expressway/Highway
- Freeway
- Major Road
- Watercourses/Rivers
- Waterbodies
- TRCA Watersheds
- Oak Ridges Moraine

Disclaimer:
Data used to create this map was compiled from TRCA's Regional Watershed Monitoring Program from 2001-2008. Sites with four or more samples over this time period were included in the analysis. The T.R.C.A. takes no responsibility for errors or omissions in the data and retains the right to make changes & corrections at anytime without notice. For further information about the data on this map, please contact the T.R.C.A. GIS Department. (416) 661-6600

Average percentage Chironomidae by site (2001-2008)

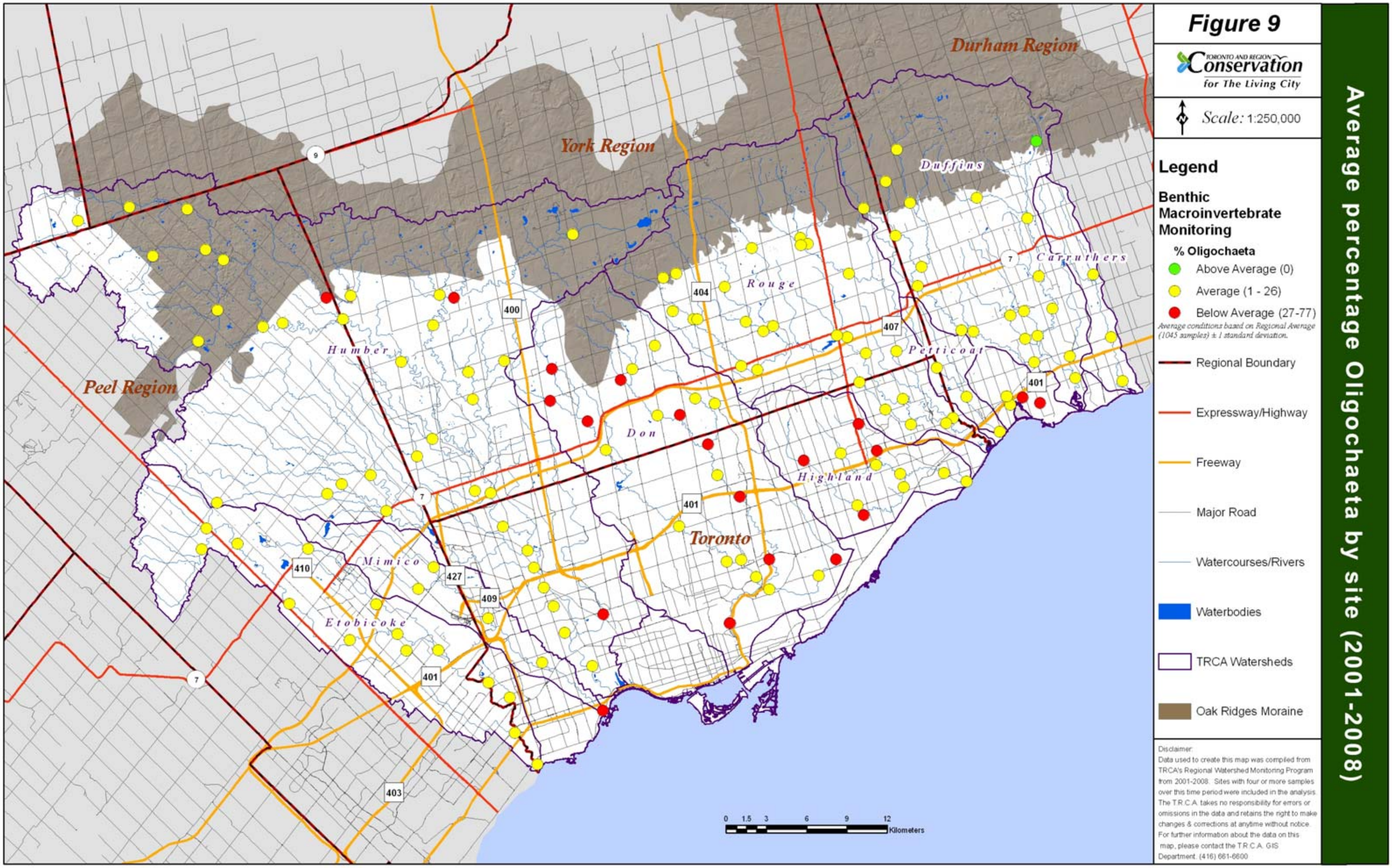
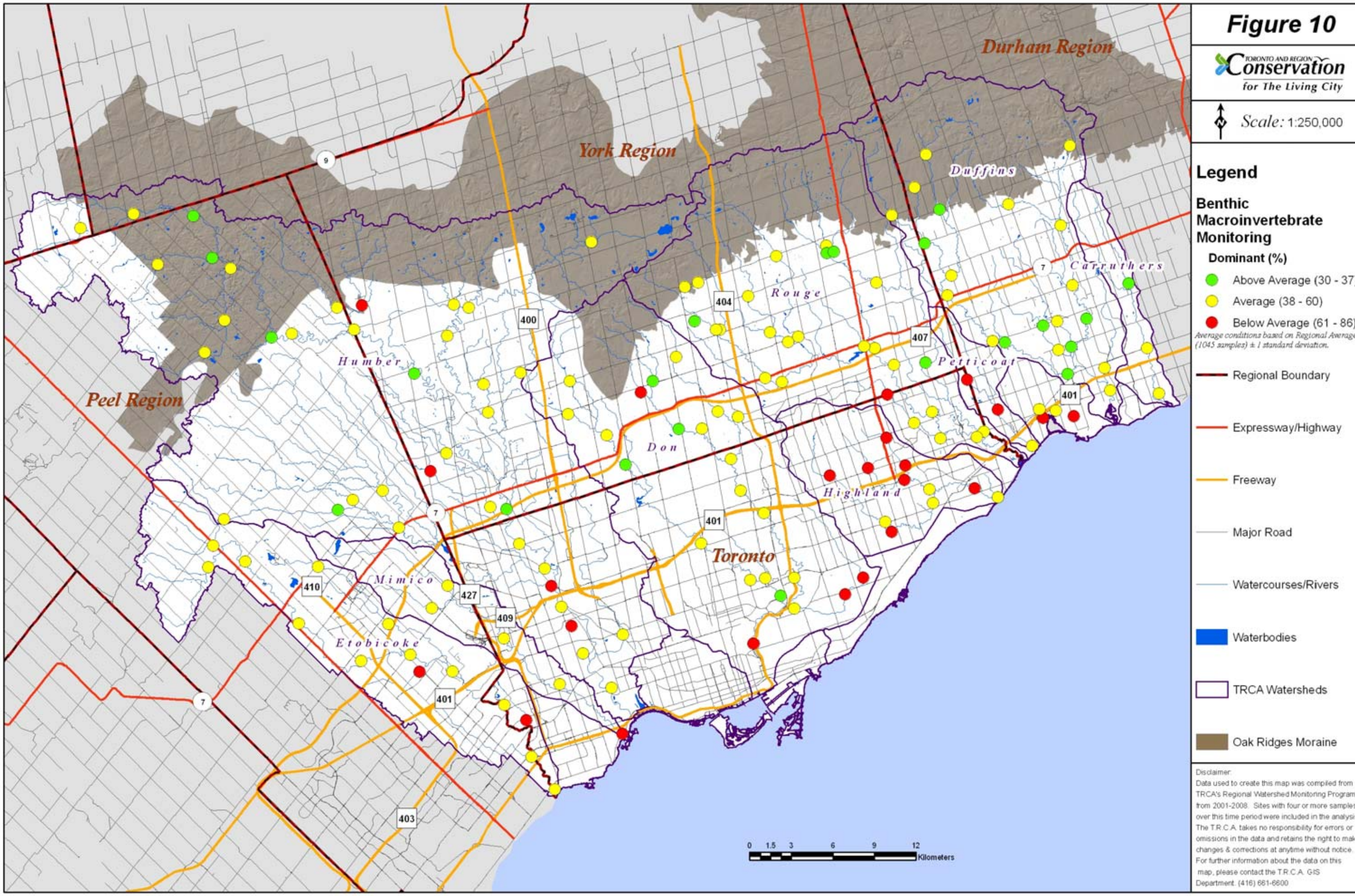


Figure 9
Toronto and Region Conservation for The Living City
Scale: 1:250,000
Average percentage Oligochaeta by site (2001-2008)
Legend
Benthic Macroinvertebrate Monitoring
% Oligochaeta
Above Average (0)
Average (1 - 26)
Below Average (27-77)
Average conditions based on Regional Average (1045 samples) ± 1 standard deviation.
Regional Boundary
Expressway/Highway
Freeway
Major Road
Watercourses/Rivers
Waterbodies
TRCA Watersheds
Oak Ridges Moraine
Disclaimer:
Data used to create this map was compiled from TRCA's Regional Watershed Monitoring Program from 2001-2008. Sites with four or more samples over this time period were included in the analysis. The T.R.C.A. takes no responsibility for errors or omissions in the data and retains the right to make changes & corrections at anytime without notice. For further information about the data on this map, please contact the T.R.C.A. GIS Department. (416) 661-6600
Durham Region
York Region
Peel Region
Toronto
Duffins
Carruthers
Rouge
Petticoat
Humber
Don
Highland
Mimico
Etobicoke
0 1.5 3 6 9 12 Kilometers
400
404
407
401
427
409
410
403
7
9

Figure 10



Average percentage dominant family by site (2001-2008)

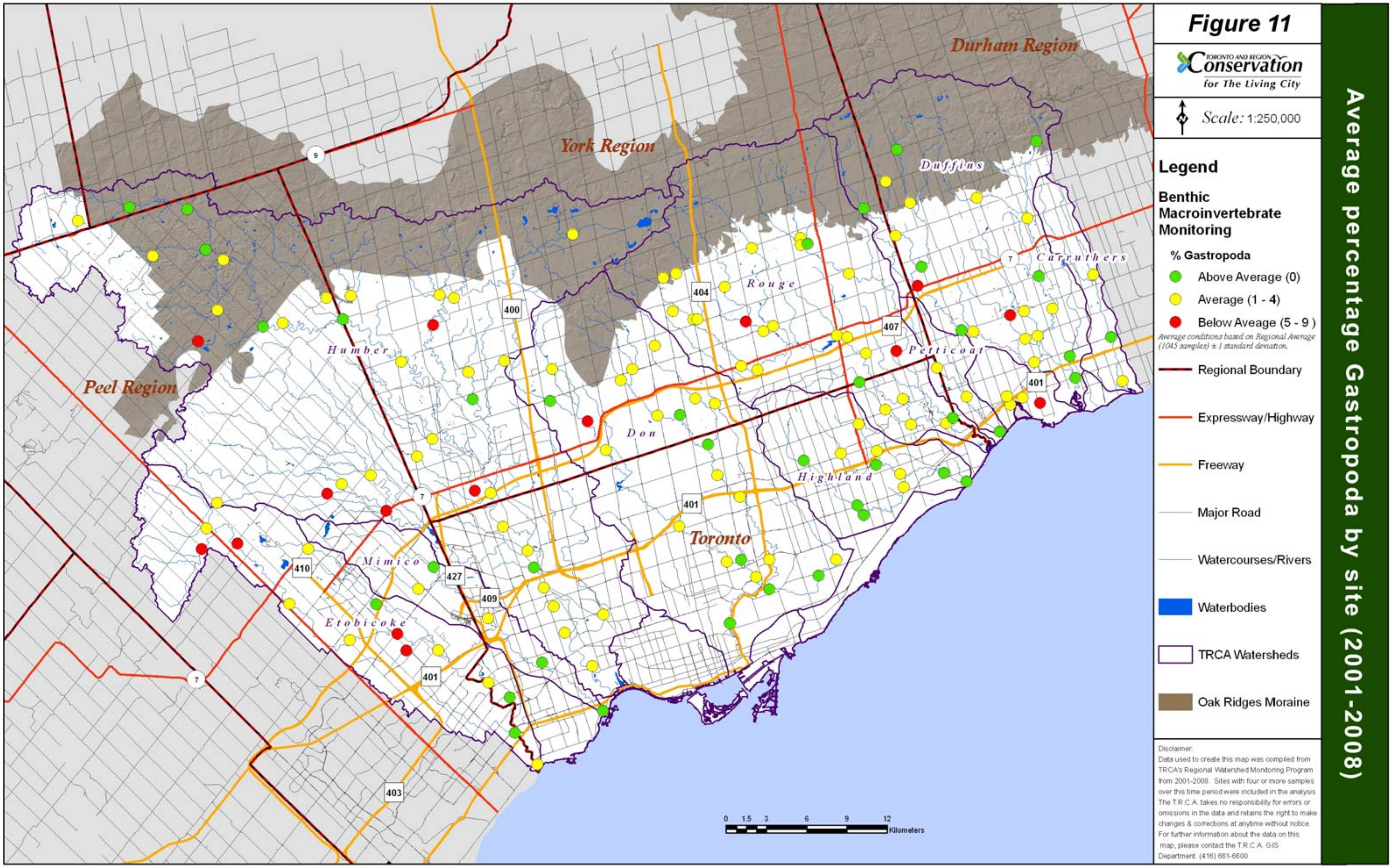


Figure 11
Toronto and Region Conservation for The Living City
Scale: 1:250,000
Average percentage Gastropoda by site (2001-2008)
Legend
Benthic Macroinvertebrate Monitoring
% Gastropoda
Above Average (0)
Average (1 - 4)
Below Aveage (5 - 9)
Average conditions based on Regional Average (1045 samples) ± 1 standard deviation.
Regional Boundary
Expressway/Highway
Freeway
Major Road
Watercourses/Rivers
Waterbodies
TRCA Watersheds
Oak Ridges Moraine
Disclaimer:
Data used to create this map was compiled from TRCA's Regional Watershed Monitoring Program from 2001-2008. Sites with four or more samples over this time period were included in the analysis. The T.R.C.A. takes no responsibility for errors or omissions in the data and retains the right to make changes & corrections at anytime without notice. For further information about the data on this map, please contact the T.R.C.A. GIS Department. (416) 661-6600
Durham Region
York Region
Peel Region
Toronto
Duffins
Carruthers
Rouge
Petticoat
Humber
Don
Highland
Mimico
Etobicoke
0 1.5 3 6 9 12 Kilometers

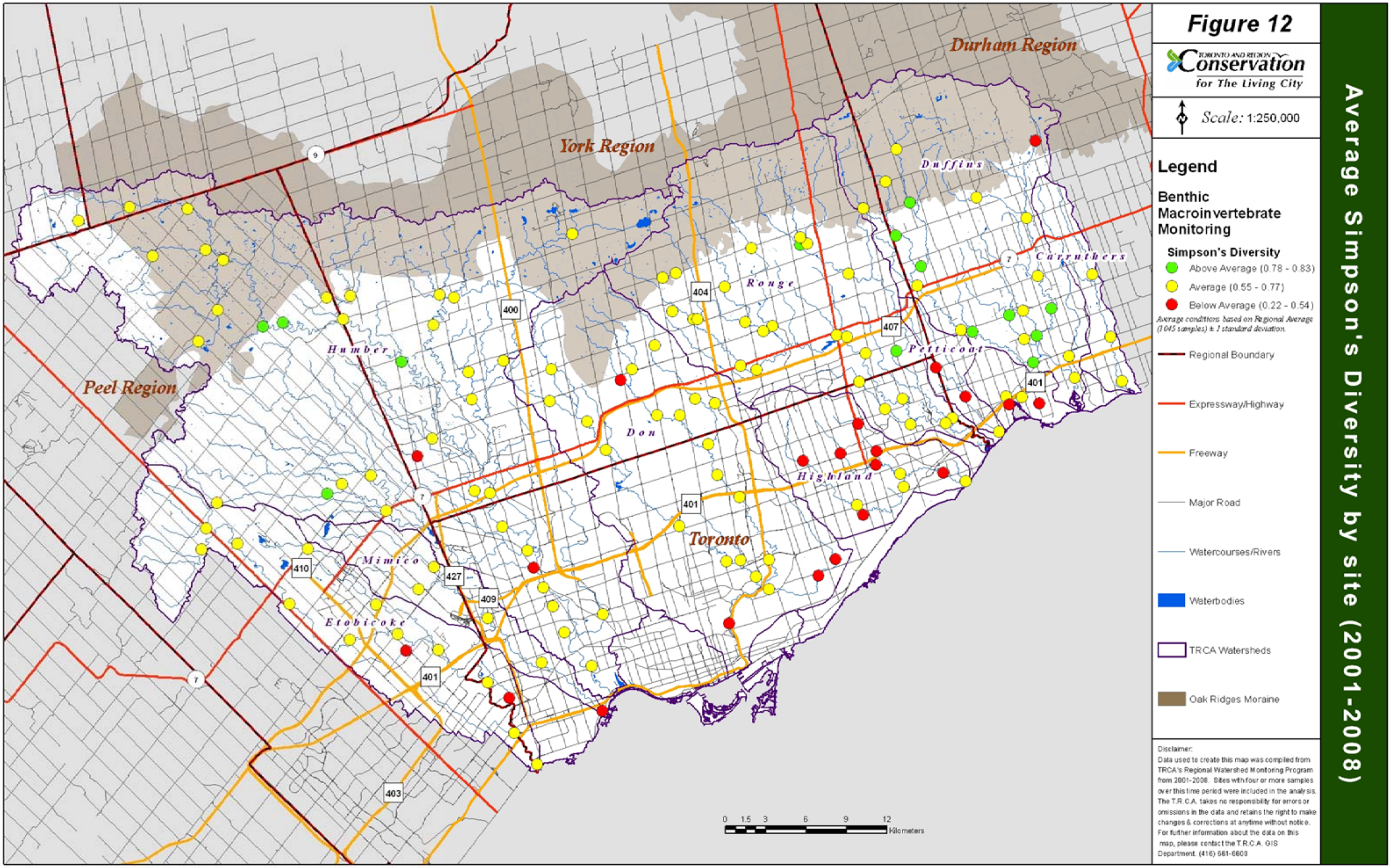
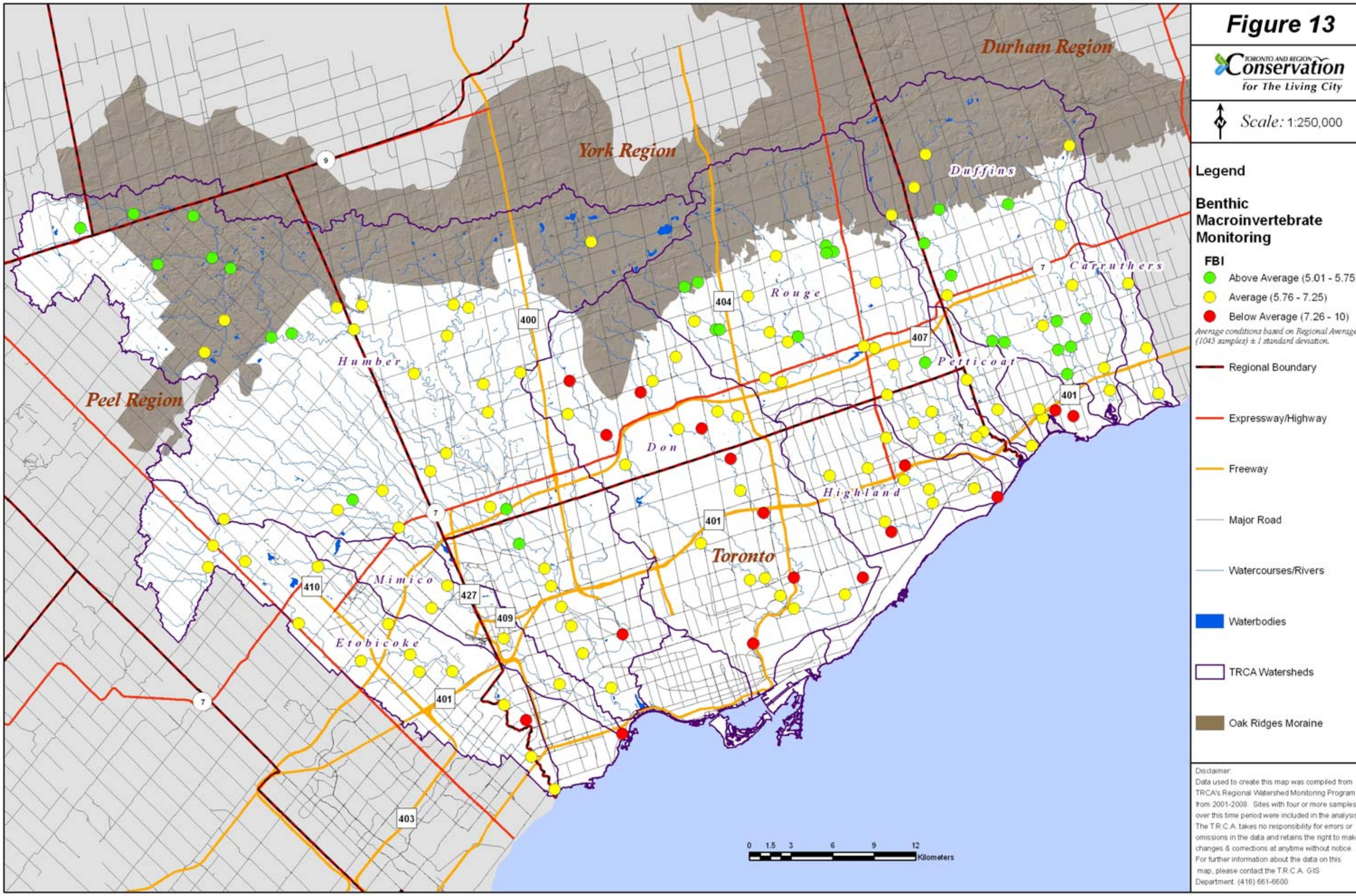


Figure 12
TORONTO AND REGION Conservation for The Living City
Scale: 1:250,000
Legend
Benthic Macroinvertebrate Monitoring
Simpson's Diversity
Above Average (0.78 - 0.83)
Average (0.55 - 0.77)
Below Average (0.22 - 0.54)
Average conditions based on Regional Average (1045 samples) ± 1 standard deviation.
Regional Boundary
Expressway/Highway
Freeway
Major Road
Watercourses/Rivers
Waterbodies
TRCA Watersheds
Oak Ridges Moraine
Disclaimer:
Data used to create this map was compiled from TRCA's Regional Watershed Monitoring Program from 2001-2008. Sites with four or more samples over this time period were included in the analysis. The T.R.C.A. takes no responsibility for errors or omissions in the data and retains the right to make changes & corrections at anytime without notice. For futher information about the data on this map, please contact the T.R.C.A. GIS Department. (416) 661-6600
Average Simpson's Diversity by site (2001-2008)
Durham Region
York Region
Peel Region
Toronto
Duffins
Carruthers
Rouge
Petticoat
Humber
Don
Highland
Mimico
Etobicoke
0 1.5 3 6 9 12 Kilometers



Average Hilsenhoff Family Biotic Index (FBI) score by site (2001-2008)

3.1.1.3 Correspondence Analysis

Correspondence analysis (CA) was was used to summarize BMI community data from 2002. A total of 125 sites were used for the CA and the results are presented in Figures 14 to 16. Figure 14 displays the association of BMI families along with the sites used for analysis. This figure is quite busy and is therefore reproduced in Figures 15 without the site locations and in Figure 16 without the BMI families to reduce the complexity of the figures.

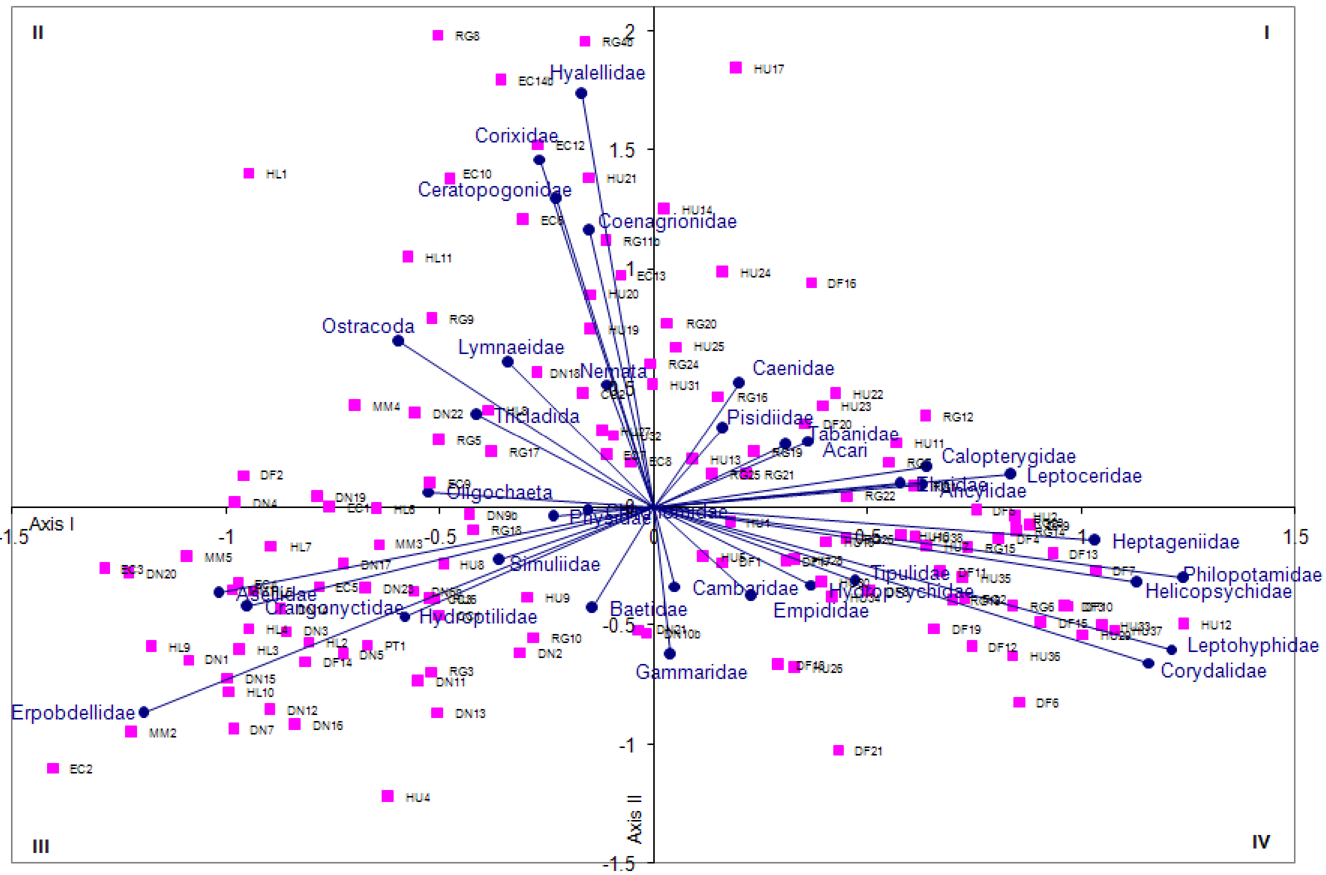


Figure 14. Correspondence analysis for 2002 BMI data collected from 125 sites across the TRCA region (sites and BMI families)

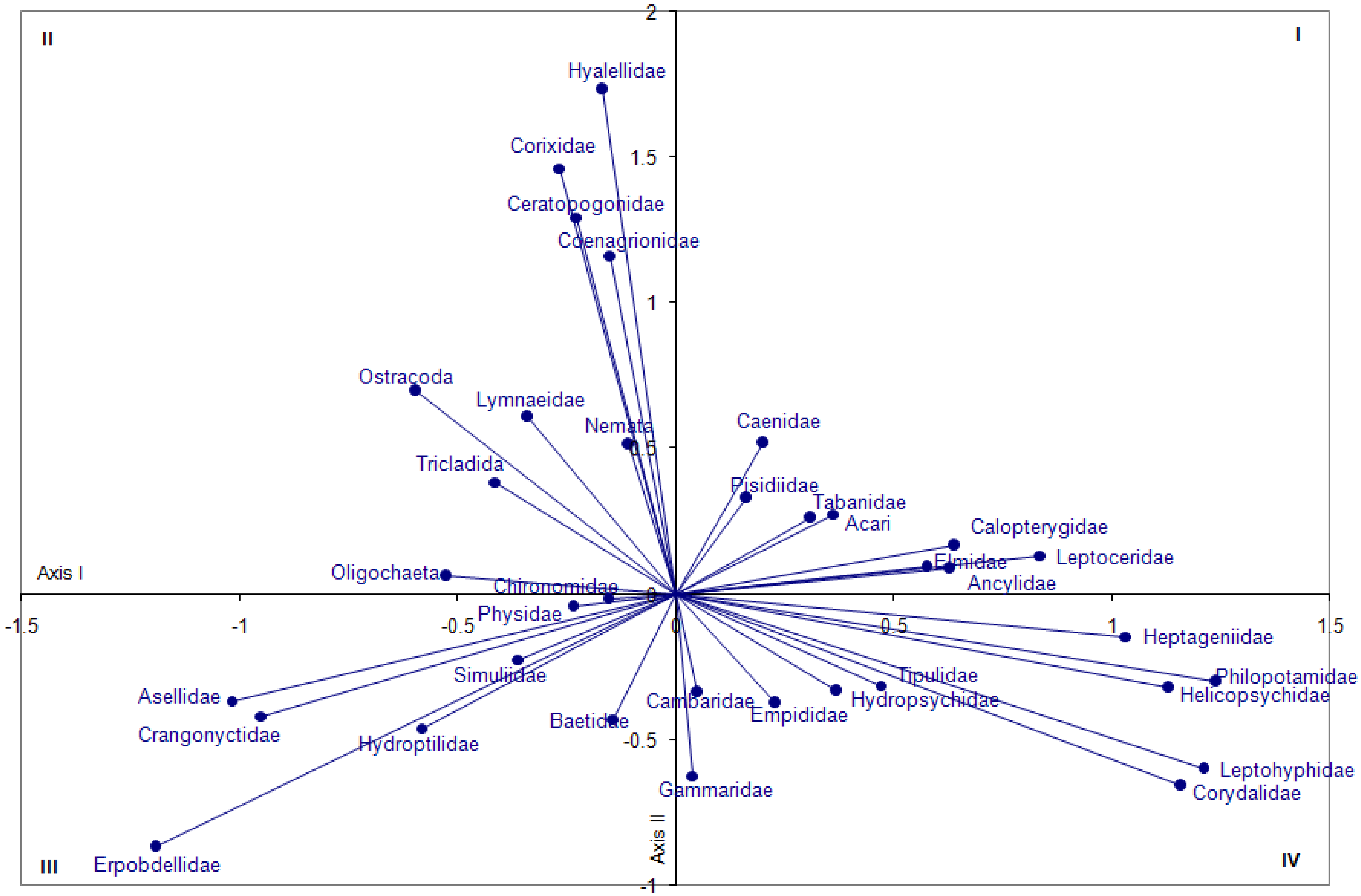


Figure 15. **Correspondence analysis for 2002 BMI data collected from 125 sites across the TRCA region (BMI only)**

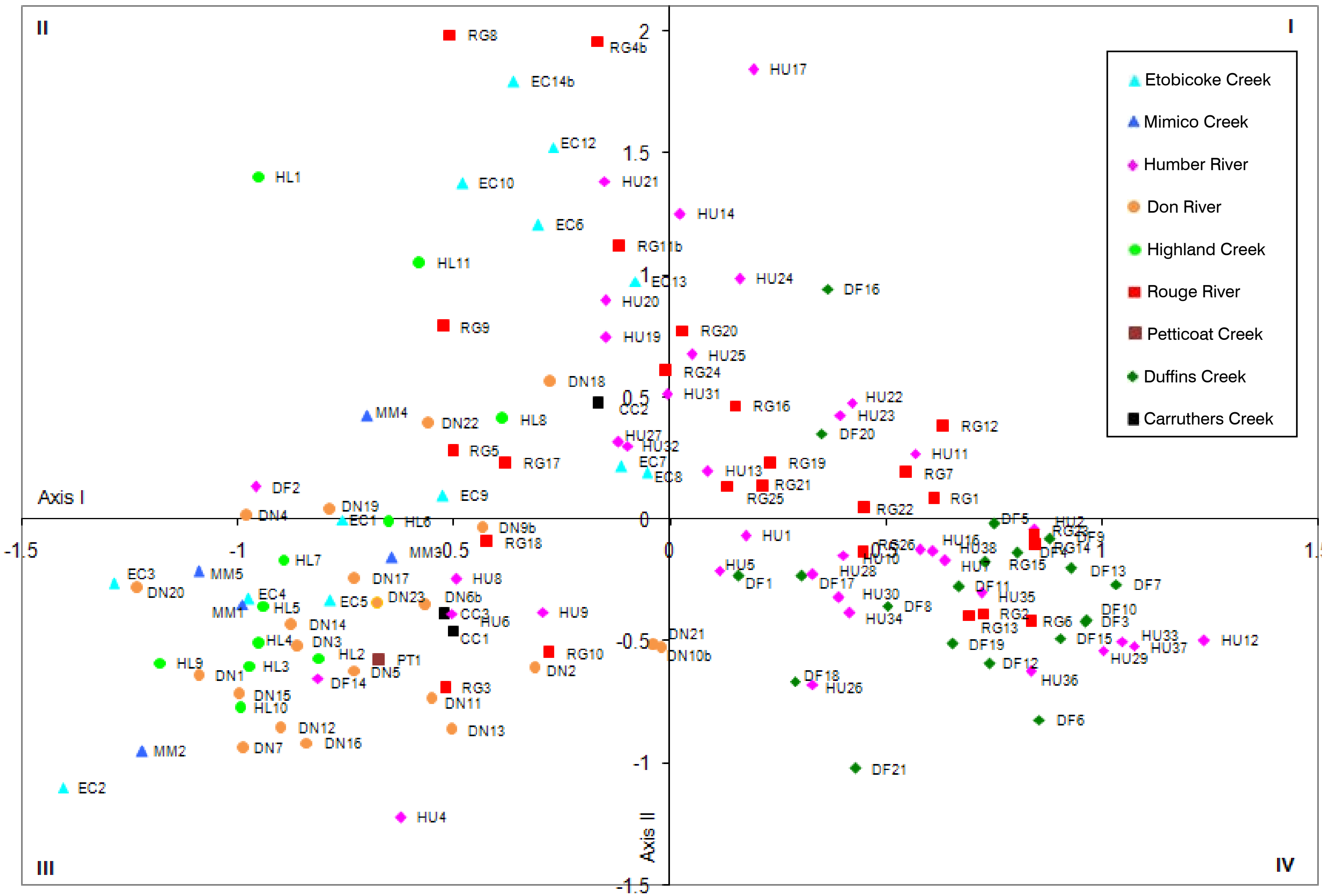


Figure 16. **Correspondence Analysis for 2002 BMI data collected from 125 sites across the TRCA region (sites only)**

The first three CA axes accounted for 30% of the variation in the BMI community (Appendix A). The CA reveals a clear separation of families along Axis I. Benthic invertebrate families which are considered to sensitive to environmental disturbance (e.g. Leptohyphidae, Helicopsychidae, Heptageniidae) are found on the right side of the plot while families which are considered tolerant to environmental stress (e.g. Oligochaeta, Erpobdellidae, Asellidae) are found on the left side of the plot. The right side of the figure contains sites from only three watersheds: Duffins Creek, Humber River and Rouge River. With the exception of two sites (DF002WM, DF014WM), all of the samples from Duffins Creek are located in either Quadrant I or IV (right side). The majority of the Humber River and Rouge River sites in Quadrant I or IV are from the upper reaches of these two watersheds. Sites representing all nine watersheds (Frenchman's Bay was not sampled in 2002) were located in Quadrants II or III (left side) of the plot. All Etobicoke Creek, Mimico Creek, Don River, Highland Creek, Petticoat Creek and Carruthers Creek stations were located in Quadrants II or III.

3.1.2 Temporal Trends

A total of 133 sites were sampled a minimum of six times from 2002-2008. Jurisdictional index values over time are presented in Figure 17. Three of the ten indices had significant trends ($p<0.05$) using the Mann-Kendall test: % Oligochaeta ($S=2.403$, $p=0.016$), FBI ($S=2.103$, $p=0.035$) and Simpson's Diversity ($S = -2.103$, $p = 0.035$). The % Oligochaeta and FBI indices increased significantly over time and the Simpson's Diversity index decreased over time which suggests that the jurisdictional watershed health decreased from 2002 to 2008. Three other indices were nearly significant ($p=0.07$): # Ephemeroptera Families, Family Richness and Dominant Family. The # Ephemeroptera Families and Taxa Richness both showed decreasing trends while the Dominant Family index showed an increasing trend. Again, these trends suggest that jurisdictional watershed health has decreased over time.

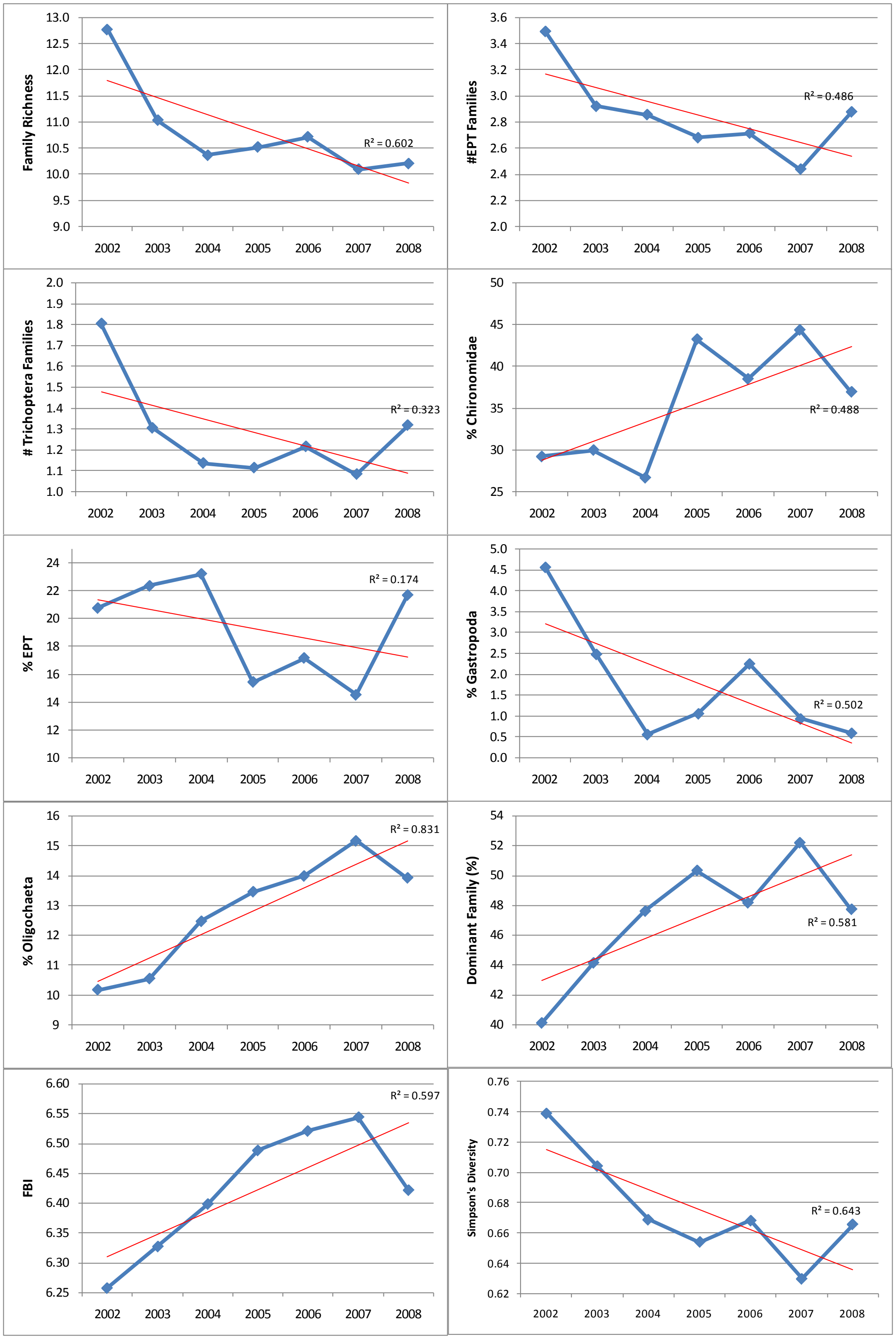


Figure 17. Jurisdictional benthic invertebrate index values over time (N=133 sites)

3.1.3 Relationships with Environmental Variables

3.1.3.1 Regression Analysis

Biotic responses were modelled using multiple linear regressions with a variety of X-variable predictors (land-use, habitat) and each of the BMI taxonomic composition indices as the Y-variable responses. Detailed results for the regression analysis are presented in Appendix A with a summary of the trends presented in Table 4.

Both linear and curvilinear (e.g. logarithmic curve) have been used to describe the relationship between indices and environmental variables in the literature. Examples of linear models include Bazinet *et al*. (2010) and Morse *et al*. (2003) and examples of non-linear relationships include Stanfield and Kilgour (2006); Stepenuck *et al*. (2002), Ourso and Frenzel (2003) and Walsh *et al*. (2005). Non-linear relationships have been used to describe a threshold response of benthic community assemblages to environmental variables whereby further increases in the environmental variable does not result in further deterioration of biotic communities. For example, Stanfield and Kilgour (2006) showed that at 10% impervious cover (i.e. approximately 50% urban cover), BMI communities in southern Ontario consisted of mainly tolerant assemblages. Both linear and curvilinear relationships were tested and were considered significant at $\alpha<0.05$.

Several environmental variables had strong, significant linear relationships with the remaining indices. Of the 25 environmental variables used, 7 (% Urban, % Rural, % Forest, % L2 Cover, % L4 Cover, Road Density, Stream Order) were significantly related to all (exception % Gastropoda) of the biological indices. The % Urban index had the strongest linear relationship with the indices (R^2 = 0.032-0.439, F = 4.004-96.171). The strongest relationship was with the FBI and Family Richness indices while the poorest, yet still significant, relationship was with the % EPT index. Road Density also had a strong relationship with the indices (R^2 = 0.044-0.409, F = 5.630-85.361). Again the strongest relationship was with FBI and Family Richness but the weakest, yet still significant, relationship was with % Chironomidae.

In general, the GIS derived indices tended to have more significant relationships with the biological variables compared to the OSAP derived variables. This suggests that landscape level stressors are more effective for describing the BMI than site specific stressors. For example, average width and D84 did not have significant linear relationships with any of the biological indices. The site specific descriptors which best described the BMI community were % Glides, followed by % Pools and % Riffles (8 indices, 6 indices, 5 indices; respectively). The number of BMI indices related to % Pools,% Riffles, and % Glides was much lower than with GIS derived variables (e.g. % Urban, % Forest).

For all of the significant relationships, the directions of the trends were as expected (see Table 1). For example, as environmental disturbance (e.g. % Urban) increased, the % EPT, Family Richness, # EPT Families and Simpson's Diversity decreased while % Oligochaeta, % Chironomidae, % Dominant Family and FBI increased. The direction of the relationships between

Table 4. Summary of linear regression trends between environmental variables and biological indices

	% Urban	% Urbanizing	% Rural	% Beach/Bluff	% Forest	% Meadow	% Sucessional	% Wetland	% L1 Cover	% L2 Cover	% L3 Cover	% L4 Cover	% L5 Cover	Catchment Area	Road Density	Stream Order	Average Width	Average Depth	Width/Depth Ratio	D16	D50	D84	% Pools	% Riffles	% Glides
% EPT	**↓**	↑	**↑**	↓	**↑**	↑	↑	↑	↓	**↑**	**↑**	**↓**	↓	**↑**	**↓**	**↑**	↑	**↓**	**↑**	**↑**	**↑**	↑	**↓**	**↑**	**↑**
% Gastropoda	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑	↓	↓	↓	↓	↓	↑	↓	↓	↓	↑	↓	↑	↑
% Oligochaeta	**↑**	↑	**↓**	↓	**↓**	↓	**↓**	**↓**	↓	**↓**	**↓**	**↑**	**↑**	↓	**↑**	**↓**	↓	**↑**	↓	↓	↓	↓	**↑**	**↓**	**↓**
% Chironomidae	**↑**	↑	**↓**	↑	**↓**	↓	↓	**↑**	↓	**↓**	↓	**↑**	↑	↓	**↑**	**↑**	↓	↑	↓	↓	↑	↓	**↑**	↓	↓
Family Richness	**↓**	↑	**↑**	↓	**↑**	**↑**	**↑**	**↑**	↓	**↑**	**↑**	**↓**	**↓**	↓	**↓**	**↑**	↓	↓	↓	↓	↓	↓	↓	↑	**↑**
# Trichoptera Families	**↓**	↑	**↑**	↑	**↑**	↑	**↑**	**↑**	↓	**↑**	**↑**	**↓**	**↓**	↑	**↓**	**↑**	↑	↓	**↑**	↓	↓	↓	**↓**	**↑**	**↑**
# EPT Families	**↓**	↑	**↑**	↓	**↓**	**↑**	**↑**	**↑**	↓	**↑**	**↑**	**↓**	**↓**	**↑**	**↓**	**↑**	↑	**↓**	**↑**	↓	↓	↓	**↓**	**↑**	**↑**
% Dominant Family	**↑**	↓	**↑**	↑	**↑**	**↓**	↓	**↓**	**↑**	**↓**	**↓**	**↑**	**↑**	↓	**↑**	**↓**	↑	↑	↓	↑	↓	↑	↑	↓	**↓**
Simpson's Diversity	**↓**	↑	**↑**	↓	**↓**	**↑**	↑	**↑**	**↓**	**↑**	**↑**	**↓**	**↓**	↑	**↓**	**↑**	↓	↓	↑	↓	↓	↓	↓	↑	**↑**
FBI	**↑**	↓	**↓**	↑	**↓**	**↓**	**↓**	**↓**	↓	**↓**	**↓**	**↑**	**↑**	↓	**↑**	**↓**	↑	**↑**	↓	↑	↑	↑	**↑**	**↓**	**↓**

Note: Shaded cells indicate significant trends

% L2 and % L3 Cover were the same (although the relationship with % L3 and % Chironomidae was not significant) and were the opposite of the trends with % Urban land cover while the relationships between % L4 and % L5 cover were similar (although the relationship with % L5 and % Chironomidae was not significant) and mimicked the trends with % Urban land cover. This suggests that decreases in urban area and road density as well as increases in natural cover will maintain or improve the health of the TRCA's watersheds in the future.

Curvilinear relationships have previously been used to develop thresholds for environmental variables. Several studies have shown that watershed health decreases dramatically at greater than 5-15% impervious cover (Jones and Clark 1987, Schueler 1994, May *et al*. 1997, Ourso and Frenzel 2003, Shaver and Maxted 1995, Stanfield and Kilgour 2006, Yoder *et al*. 1999). Percent Forest in the upstream catchment was the only index to have significant curvilinear (logarithmic) relationships with each of the biological indices (with the exception of % Gastropoda) in this study. Percent Forest was also significantly linearly related to the environmental variables but the logarithmic relationship was stronger. FBI ($F=85.225$, $R^2=0.409$, $p>0.0001$), Family richness ($F=83.582$, $R^2=0.303$, $p>0.0001$) and # EPT Families ($F=44.975$, $R^2=0.267$, $p>0.0001$) had the strongest logarithmic relationships with % Forest in the upstream catchment (Figure 18). In all three cases, when % Forest is greater than 5-10%, all three indices improved substantially.

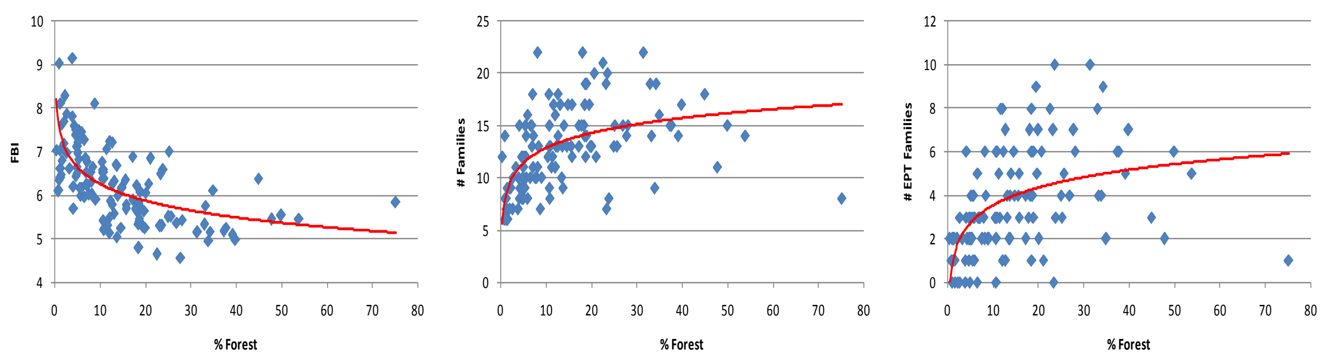


Figure 18. Strongest logarithmic relationship between % Forest and three biological indices (FBI, Family Richness, # EPT Families)

3.1.3.2 Canonical Correspondence Analysis

CCA was performed using the 2002 BMI data (125 sites) along with the habitat and land-use variables. A CCA of the BMI, habitat and land-use data is presented in Figure 19.

The CCA plot was based on 35 families from 125 sites and 25 environmental variables. The length of the vectors represents their relative importance and their direction relates to approximate correlation with the axes. The CCA revealed that the BMI communities were strongly influenced by *(i)* the percentage of urban land cover, (*ii*) road density, (*iii*) the percentage of rural land cover, (*iv*) the percentage L3 cover, and (*v*) the percentage forest along Axis I. In other words, sites comprised mainly of tolerant families associated with higher urbanization are located on the left

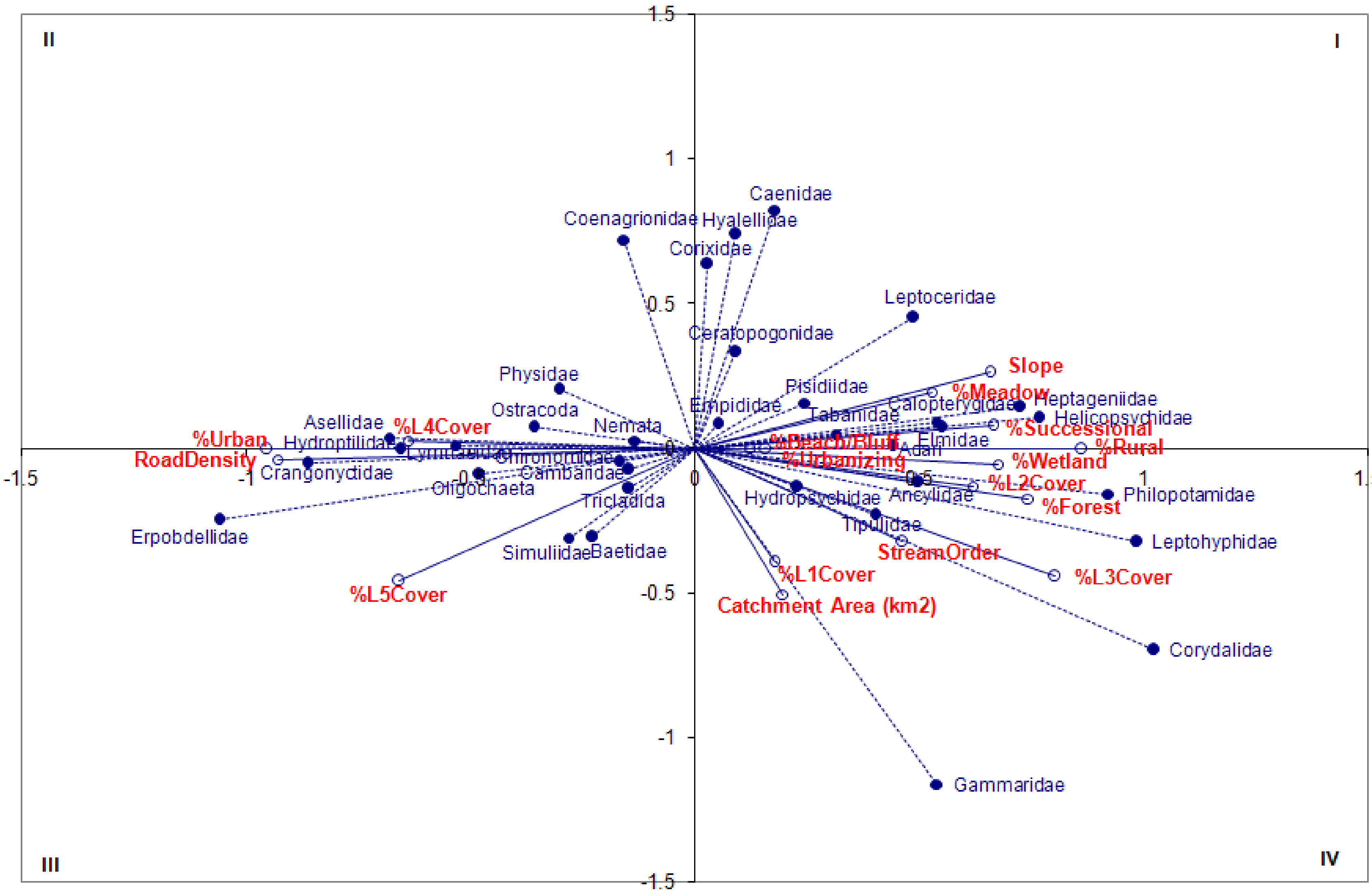


Figure 19. Canonical Correspondence Analysis (CCA) for BMI, habitat, and land-use variables for 125 sites across the TRCA's jurisdiction

side of the plot while sensitive species associated with high quality habitat (e.g. high % Forest) were located on the right side of the pot. Habitat variables such as the percentage of pools and riffles had a weak influence on Axis II. Again, this indicates that landscape variables had a stronger influence of the BMI community compared to habitat variables.

The first three axes accounted for 53.9% of the constrained variation in the BMI community with the first axis accounting for 28.5% (Appendix A). By comparing the eigenvalues from the CA to the CCA, the environmental variables used accounted for 34.4% of the total variation in the BMI community. Other factors such as water quality, hydraulic habitat, and organic food resources may account for the remaining variation in the BMI community (e.g. Bazinet *et al*. 2010, Kilgour *et al*. 2009, Vinson and Hawkins 1998; Ourso and Frenzel 2003; Lamouroux *et al*. 2004). Since CCA is a special case of multiple linear regression, it is not surprising that the environmental variables which had strong linear relationships with the biological indices are the same as the main factors influencing the CCA axes.

3.2 Watershed Analysis

The indices for the 2002-2008 BMI data were analyzed on a watershed basis. Sites which were sampled a minimum of 6 times over this time period have been included in the analysis. Due to lack of data, there is no analysis for the Petticoat Creek and Frenchman's Bay watersheds. Additional information is provided in Appendix A.

Data are presented in graphical format with two time series lines (watershed - blue, regional average - red), a trend line for the watershed (blue) and a regional average line (green). The two time series lines are based on the average value for the index for each year. The trend line for the watershed time series gives an indication of the trend direction over time (increasing, decreasing, steady-state). The strength of this trend is described by the R^2 value with higher values (maximum value = 1) indicating stronger trends. The green line is the average index value for the region from 2002-2008 for all sites included in the analysis.

3.2.1 Etobicoke Creek

The index results for Etobicoke Creek are shown in Figure 20. The watershed average index scores for Family Richness, # EPT Families, # Trichoptera Families, % EPT, % Oligochaeta, and Simpson's Diversity were all below the jurisdictional average while % Gastropoda, % Dominant Family and FBI were above the jurisdictional average. These results suggest that the health of the Etobicoke Creek watershed is below that of the TRCA region as a whole. When compared to the reference site normal for southwestern Ontario (Jones 2008), % Chironomidae and % Oligochaeta were within the normal range while Family Richness, % EPT, and FBI were outside the normal range. Family Richness, % EPT and FBI were all worse than the reference condition. Again, these results suggest that the health of the Etobicoke Creek watershed is poorer in relation to both the TRCA jurisdiction and southwestern Ontario.

Family Richness, # EPT Families, # Trichoptera Families, % EPT, % Oligochaeta, and Simpson's Diversity all showed decreasing trends over time. The % Chironomidae, % Dominant Family and % Oligochaeta indices showed an increasing trend but only the % Chironomidae index was nearly statistically significant (p=0.06). Although not significant, these results suggest that the health of the Etobicoke Creek is declining over time. Should these trends continue, the results will likely become statistically significant with more monitoring data.

3.2.2 Mimico Creek

The index results for Mimico Creek are presented in Figure 21. In general, the Mimico Creek watershed can be considered less healthy than the jurisdictional average. For example, the % Oligochaeta index is much higher in the Mimico Creek watershed (>40%) compared to the jurisdictional average (13%). The average FBI value from 2002-2008 was 7.27 which was much higher than the jurisdictional average of 6.46. The 7.27 FBI value for Mimico Creek corresponds to a rating of "very poor" which is worse than the jurisdictional average rating of "fairly poor". When compared to the reference site normal for southwestern Ontario (Jones 2008), % Chironomidae were within the normal range while Family Richness, % EPT, and % Oligochaeta and FBI were outside the normal range. Family Richness, % EPT, % Oligochaeta and FBI were all worse than the reference condition.

Family Richness, # EPT Families, % EPT, and Simpson's Diversity all showed decreasing trends over time. FBI, % Trichoptera, % Dominant Family, % Oligochaeta all showed increasing trends over time. The increasing FBI trend was nearly significant (p=0.09). The trends seen in these indices indicate that the health of the Mimico watershed is decreasing over time. Although increases in the % Trichoptera index are usually seen as a positive results (e.g. improvement in watershed health), the increase in the % Trichoptera index in Mimico Creek was due to an increase in a tolerant family (i.e. Hydroptilidae).

Figure 20. BMI indices for Etobicoke Creek compared to jurisdictional average index values

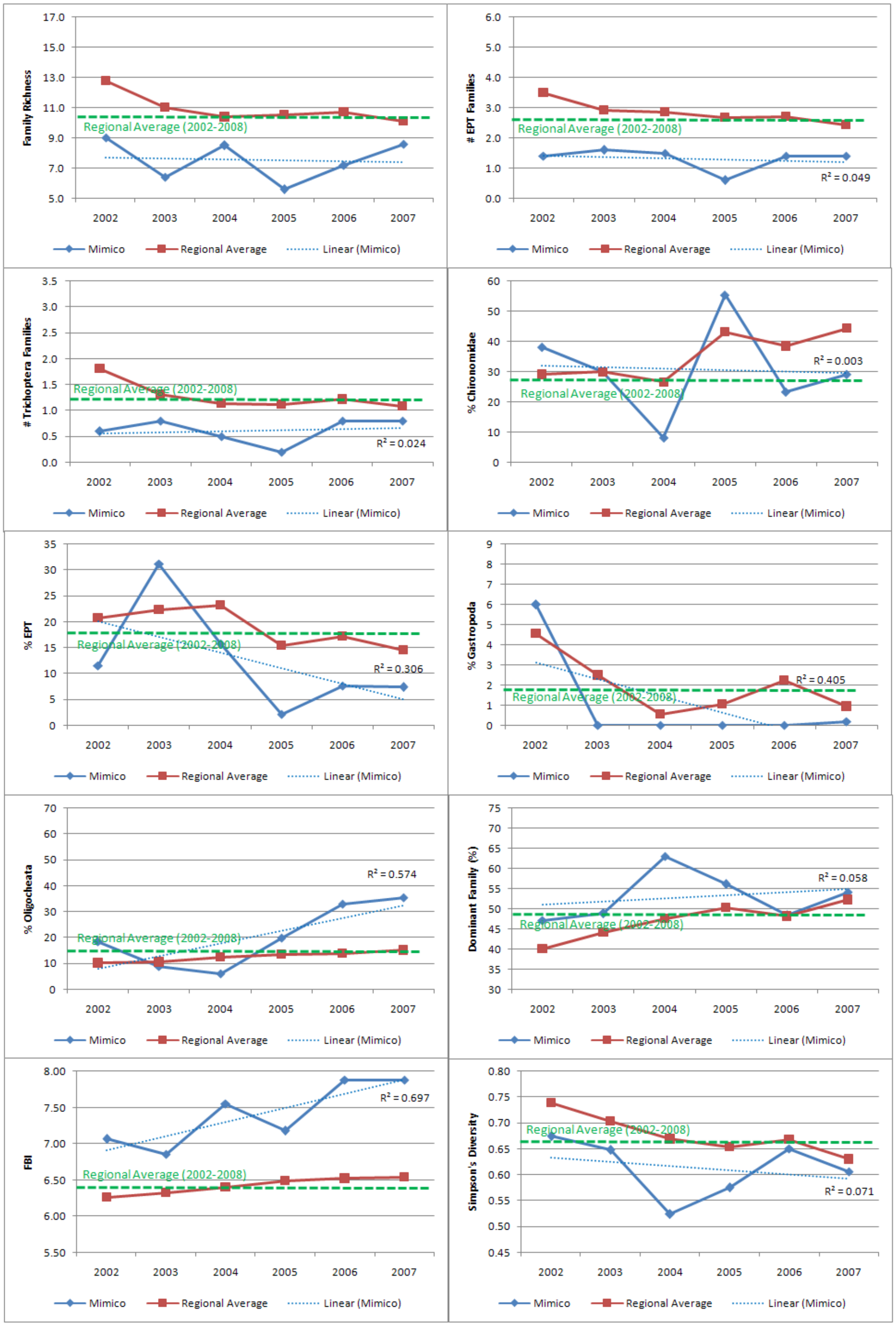


Figure 21. BMI indices for Mimico Creek compared to jurisdictional average index values

3.2.3 Humber River

The index results for the Humber River watershed are presented in Figure 22. In general, the Humber River watershed can be considered healthier than the jurisdictional average. Five indices (Family Richness, # EPT Families, # Trichoptera Families,% EPT and Simpson's Diversity) were all above the jurisdictional average and only two indices were below the jurisdictional average (% Oligochaeta, FBI) indicating a relatively healthy watershed. When compared to the reference site normal for southwestern Ontario (Jones 2008), % Chironomidae, % EPT, and FBI were within the normal range while Family Richness, and % Oligochaeta were outside the normal range although both were only slightly outside the normal range. This suggests that the Humber River watershed is generally healthy.

Although the health of the Humber River watershed is above the jurisdictional average, trends in the indices over time indicate that the health of the watershed is declining. The Family Richness, # EPT Families, # Trichoptera Families,% EPT and Simpson's Diversity indices all showed a decreasing trend over time with the trend for the family richness index being almost statistically significant ($p = 0.06$). The % Chironomidae, % Oligochaeta, Dominant Family and FBI indices all showed an increasing trend indicating a decrease in watershed health over time. Of these four indices, the trends for two indices (% Oligochaeta and FBI) were nearly statistically significant ($p=0.06$). The FBI value for the watershed has increased from 5.85 in 2002 and to approximately 6.3 in 2006-2008 but has remained in the "fairly poor" category. The switch to the "poor" category occurs at FBI values greater than 6.51 (to 7.25).

3.2.4 Don River

Index results for the Don River watershed over time are presented in Figure 23. The index results suggest that the Don River watershed is less healthy than the TRCA's jurisdictional average. Family Richness, # EPT Families, # Trichoptera Families, % Gastropoda, and Simpson's Diversity were all below the jurisdictional average while the FBI index was above the jurisdictional average. FBI values ranged from 7.11 to 7.39 which span the ratings of "poor" to "very poor" which suggest that very substantial to severe organic pollution is likely. At first glance, the results for % EPT composition appear to be inconsistent with the other index results. A community with a high composition of EPT organisms usually suggests a healthy ecosystem; yet, the Don River watershed was above the jurisdictional average for the % EPT index. Further investigation into the type of EPT organisms found in the Don River watershed revealed that a single Ephemeroptera family, Baetidae, made up greater than 71% of the EPT organisms found in the Don River watershed. Baetidae are ubiquitous and relatively tolerant to environmental disturbance. When compared to the reference site normal for southwestern Ontario (Jones 2008), % Chironomidae, was within the normal range while Family Richness, % Oligochaeta, % EPT and FBI were outside the normal range.

Family Richness, #EPT Families, # Trichoptera Families, % EPT, and Simpson's Diversity all showed decreasing trends over time while % Chironomidae and % Oligochaeta showed increasing trends over time. FBI results remained fairly consistent over the seven year time period. These results suggest that the health of the Don River watershed is decreasing over time or at best, remaining constant.

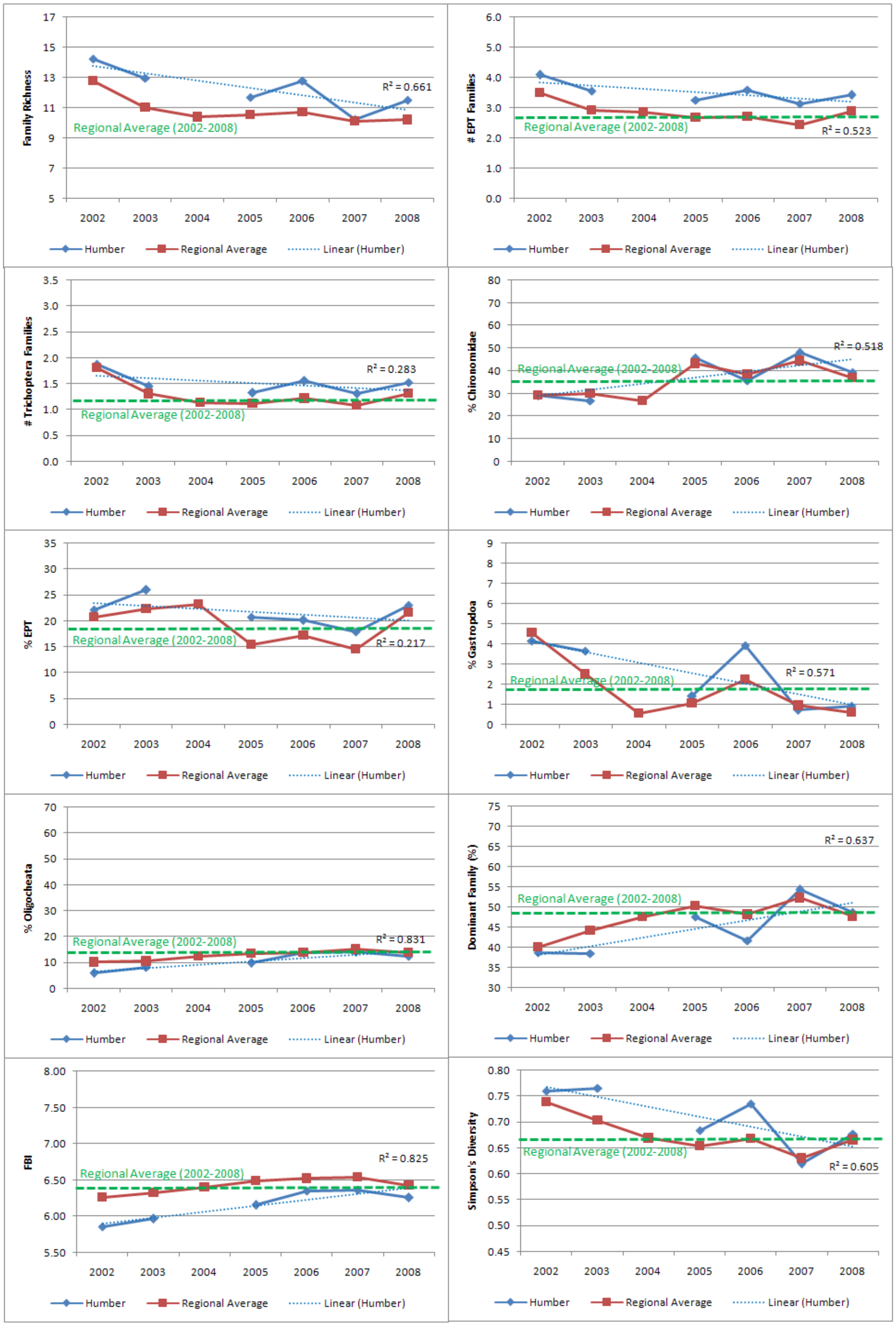


Figure 22. BMI indices for Humber River compared to jurisdictional average index values

Figure 23. BMI indices for Don River compared to jurisdictional average index values

3.2.5 Highland Creek

Index results over time for the Highland Creek watershed are shown in Figure 24. In general, the index results suggest that the Highland Creek watershed is unhealthy compared to the jurisdictional average. Family Richness, # EPT Families, # Trichoptera Families, % EPT and Simpson's Diversity were all below (worse than) the jurisdictional average. Percent Chironomidae, % Oligochaeta, dominant family and FBI all had values above the jurisdictional average which suggest lower health as well. When compared to the reference site normal for southwestern Ontario (Jones 2008), % Chironomidae, was within the normal range while Family Richness, % Oligochaeta, % EPT and FBI were outside the normal range.

The Family Richness and Simpson's Diversity indices both showed decreases over time with the decreasing trend in family richness being statistically significant ($p = 0.02$). Percent Oligochaeta and dominant family showed increasing trends over time although neither trend was statistically significant. The remaining indices stayed relatively similar over the seven year time period. These results suggest that the health of the Highland Creek watershed may have decreased or at best, stayed the same from 2002 to 2008.

3.2.6 Rouge River

Index temporal trends for the Rouge River watershed are shown in Figure 25. The index results suggest that the Rouge River watershed can be considered healthier than the jurisdictional average. Several indices (Family Richness, #EPT Families, # Trichoptera Families % EPT, Simpson's Diversity) which suggest a healthy ecosystem were all above the jurisdictional average. The % Oligochaeta, Dominant Family and FBI indices were below the jurisdictional average which also suggest a healthy ecosystem. When compared to the reference site normal for southwestern Ontario (Jones 2008), % Chironomidae, % EPT, % Oligochaeta, and FBI were within the normal range. Of the five indices used, the only index to be outside the normal range was Family Richness. The average Family Richness for the Rouge River was 12 which is slightly outside the normal range of 13-18. This indicates that the Rouge River is generally healthy.

Family Richness, # EPT Families, # Trichoptera Families, % EPT and Simpson's Diversity indices all showed a decreasing trend from 2002 to 2008 with the family richness trend being significant ($p = 0.04$). Percentage Chironomidae, % Oligochaeta, Dominant Family and FBI indices all had decreasing trends over time. This suggests the need for continued monitoring to track changes associated with increasing urbanization in this watershed.

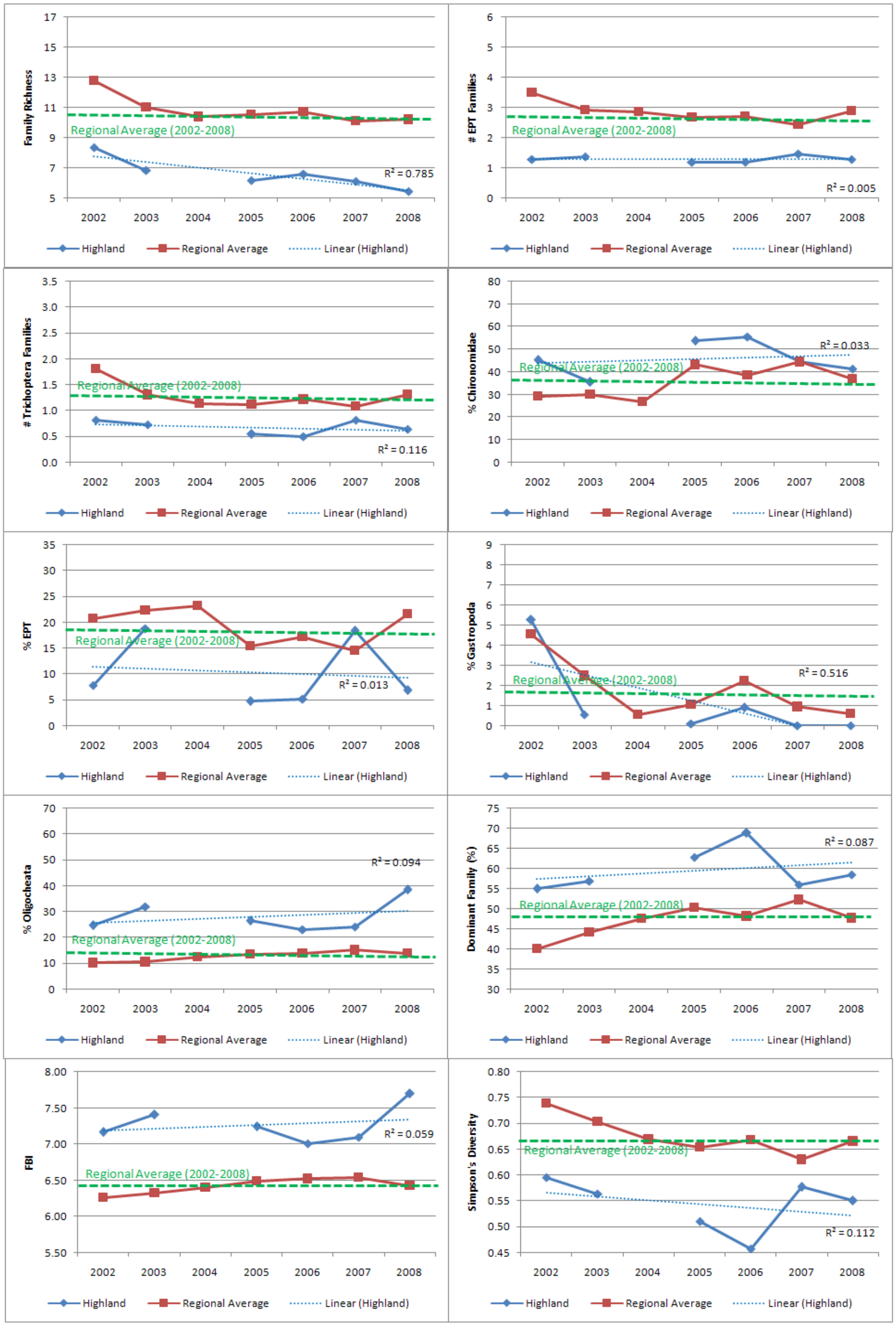


Figure 24. BMI indices for Highland Creek compared to jurisdictional average index values

Figure 25. BMI indices for Rouge River compared to jurisdictional average index values

3.2.7 Duffins Creek

Index results for the Duffins Creek watershed are shown in Figure 26 and suggest that the health of the Duffins Creek watershed is better than the jurisdictional average. The Family Richness, # EPT Families, # Trichoptera Families, % EPT and Simpson's Diversity indices were all above the jurisdictional average. Percent Oligochaeta, Dominant Family and FBI were all below the jurisdictional average. These index results suggest that Duffins Creek watershed is healthy in relation to the overall TRCA jurisdiction. When compared to the reference site normal for southwestern Ontario (Jones 2008), % Chironomidae, % EPT, % Oligochaeta, and FBI were within the normal range. Of the five indices used, the only index to be outside the normal range was Family Richness. The average Family Richness for the Duffins Creek watershed was 12.4 which is slightly outside the normal range of 13.2-17.7. This indicates that the Duffins Creek watershed is relatively healthy.

In general, the index results suggest that over the 2002 to 2008 time period, the health of the Duffins Creek watershed is declining. Family Richness, # EPT Families, # Trichoptera Families, % EPT and Simpson's Diversity all showed decreasing trends over time which suggest declining watershed health. The decreasing trend in the # EPT families, # Trichoptera families, % EPT indices were nearly significant ($p = 0.06$). The % Chironomidae, % Oligochaeta, Dominant Family and FBI indices all showed increasing trends over time which also suggests declining watershed health. The dominant family and FBI indices were close to being statistically significant ($p = 0.06$) and with additional data, these trends are likely to become statistically significant.

3.2.8 Carruthers Creek

Index results for the Carruthers Creek watershed are presented in Figure 27. The results were mixed: the # EPT Families, # Trichoptera Families and % EPT indices were below the jurisdictional average which suggests impaired watershed health compared to the rest of the TRCA jurisdiction while the % Chironomidae, % Oligochaeta, Dominant Family (below the jurisdictional average) and Simpson's Diversity (above the jurisdictional average) indices suggest watershed health is better than the average. When compared to the reference site normal for southwestern Ontario (Jones 2008), % Chironomidae and % Oligochaeta were within the normal range while Family Richness, % EPT, and FBI were outside the normal range.

The temporal trends also had mixed results. The family richness index decreased over time and % Chironomidae increased over time suggesting declining health in the watershed. But, the % Oligochaeta, Dominant Family and FBI indices decreased while the Simpson's Diversity index increased suggesting improving watershed health.

Figure 26. **BMI indices for Duffins Creek compared to jurisdictional average index values**

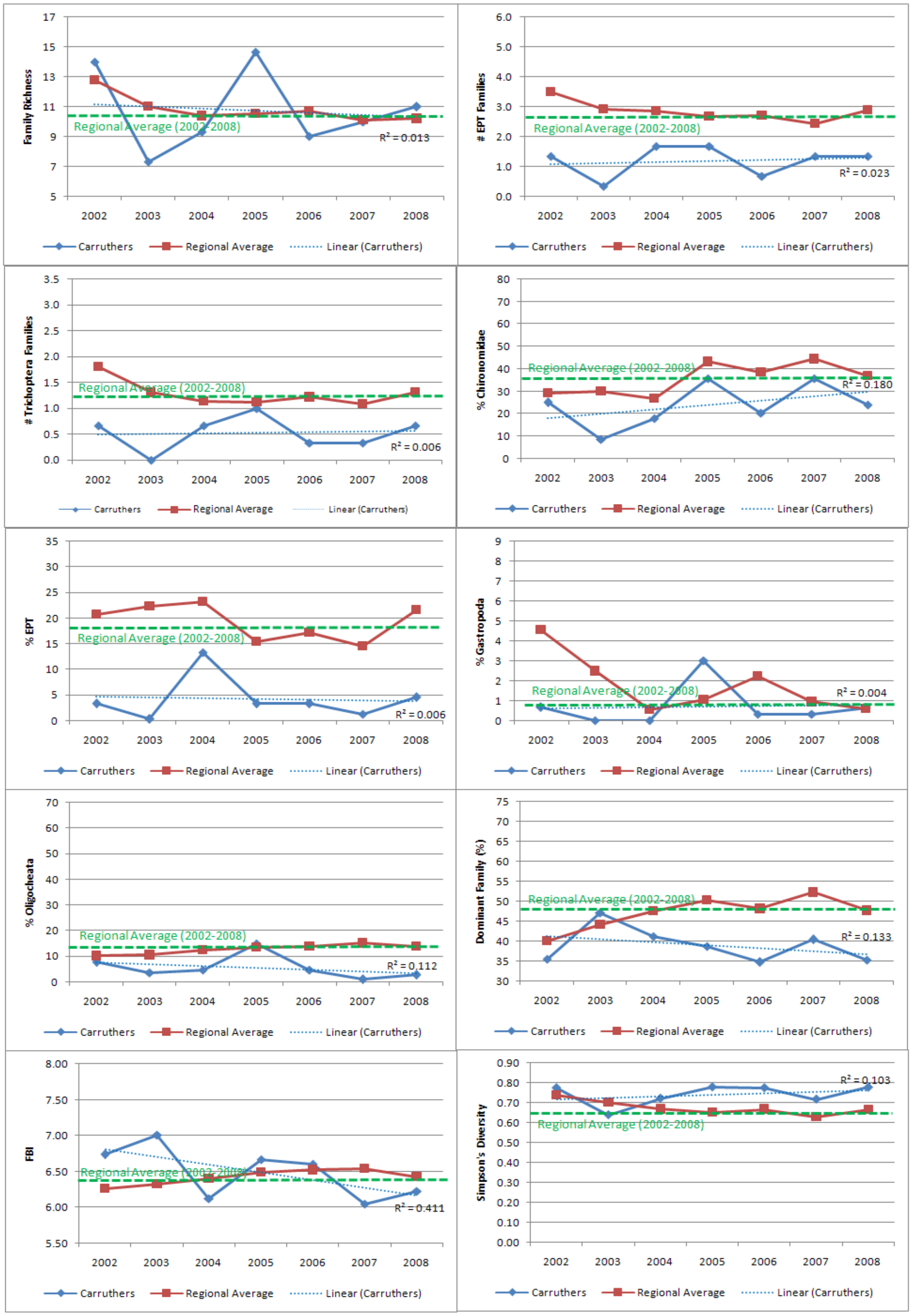


Figure 27. BMI indices for Carruthers Creek compared to jurisdictional average index values

Summary

A summary of the index trend analysis is presented in Table 5. All watersheds showed a decrease in family richness over time. The majority of watersheds had decreasing trends in the # EPT Families, # Trichoptera Families, % EPT, and Simpson's Diversity indices and increasing trends in % Chironomidae, % Oligochaeta, Dominant Family and FBI indices suggesting that, in general, the health of the watersheds within the TRCA's jurisdiction is decreasing over time.

The % Gastropoda index also showed a mainly decreasing trend over time. This would usually suggest an improvement in watershed health but in most cases, this would be contradictory to the remainder of the index results. In most cases, the 2002 results (and sometimes the 2003 results) for this index were higher than the subsequent years. From 2004 onwards, a 100+ subsample was identified rather than the whole sample. This suggests that differences in the % Gastropoda index may be due to sub-sampling techniques rather than intrinsic differences in the data. Another index should be considered for future analysis.

Table 5. Summary of Mann-Kendall trend analysis by watershed by year (2002-2008)

		Family Richness	# EPT Families	# Trichoptera Families	% Chironomidae	% EPT	% Gastropoda	% Oligochaeta	Dominant Family (%)	FBI	Simpson's Diversity
Etobicoke Creek	Trend	↓	↓	↓	↑	↓	↓	↑	↑	↓	↓
	R^2	0.180	0.134	0.226	0.819	0.428	0.449	0.381	0.386	0.100	0.251
	S	-1.127	-0.751	-0.564	1.879	-1.503	-0.750	1.127	1.503	-0.376	-1.127
	p	0.260	0.452	0.573	0.06*	0.133	0.452	0.260	0.133	0.707	0.260
Mimico Creek	Trend	↓	↓	↑	↓	↓	↓	↑	↑	↑	↓
	R^2	0.009	0.049	0.024	0.003	0.306	0.405	0.574	0.058	0.697	0.071
	S	0.000	0.564	0.188	-0.376	-1.127	0.000	1.503	0.376	1.691	-0.376
	p	1.000	0.573	0.851	0.707	0.260	1.000	0.133	0.707	0.091*	0.707
Humber River	Trend	↓	↓	↓	↑	↓	↓	↑	↑	↑	↓
	R^2	0.661	0.523	0.283	0.518	0.217	0.571	0.831	0.637	0.825	0.605
	S	-1.879	-1.127	-0.751	1.127	-0.751	-1.503	1.879	1.503	1.879	-1.503
	p	0.06*	0.260	0.452	0.260	0.452	0.133	0.06*	0.133	0.06*	0.133
Don River	Trend	↓	↓	↓	↑	↓	↓	↑	↑	↑	↓
	R^2	0.161	0.387	0.179	0.112	0.020	0.610	0.308	0.020	0.022	0.171
	S	-0.901	-0.901	-0.901	0.300	-0.601	-2.403	0.601	0.000	0.000	-0.601
	p	0.386	0.386	0.386	0.764	0.548	0.016**	0.548	1.000	1.000	0.548
Highland Creek	Trend	↓	↑	↓	↑	↓	↓	↑	↑	↑	↓
	R^2	0.785	0.005	0.116	0.033	0.013	0.516	0.094	0.087	0.059	0.112
	S	-2.254	0.118	-0.564	0.000	0.000	-1.691	0.000	0.751	0.000	-0.751
	p	0.024**	0.851	0.573	1.000	1.000	0.091*	1.000	0.452	1.000	0.452
Rouge River	Trend	↓	↓	↓	↑	↓	↓	↑	↑	↑	↓
	R^2	0.675	0.356	0.298	0.431	0.064	0.343	0.037	0.340	0.254	0.513
	S	-2.103	-0.901	-1.202	1.502	0.000	-1.202	0.000	1.202	1.202	-1.502
	p	0.035**	0.386	0.230	0.133	1.000	0.230	1.000	0.230	0.230	0.133
Duffins Creek	Trend	↓	↓	↓	↑	↓	↓	↑	↑	↑	↓
	R^2	0.129	0.617	0.494	0.725	0.804	0.084	0.629	0.672	0.775	0.614
	S	0.751	-1.879	-1.691	1.503	-1.879	0.751	1.127	1.879	1.879	-1.503
	p	0.452	0.06*	0.091*	0.133	0.06*	0.452	0.260	0.06*	0.06*	0.133
Carruthers Creek	Trend	↓	↑	↑	↑	↓	↑	↓	↓	↓	↑
	R^2	0.013	0.023	0.006	0.180	0.006	0.004	0.112	0.133	0.411	0.103
	S	0.300	0.000	0.000	0.751	0.150	0.300	-1.051	-0.901	-1.502	0.601
	p	0.764	1.000	1.000	0.453	0.881	0.764	0.293	0.368	0.133	0.548

Note: * denotes an almost statistically significant result ($0.05 > p < 0.10$)
** denotes a statistically significant result ($p < 0.05$)

4. Summary

BMI communities occurring in streams are exposed directly to the stress of pollution and the conditions of the aquatic environment. The taxonomic composition of the BMI community is influenced by the characteristics of the aquatic ecosystem in which they live; therefore, BMI communities are useful indicators for assessing watershed health. This report aimed to answer three main study objectives:

1. Is BMI taxonomic composition the same in each of the ten watersheds within TRCA's jurisdiction?
2. Are there any spatial or temporal trends in the BMI community composition?
3. Do all sampled locations have similar biological health?

The BMI community was shown to be different within a watershed as well as between watersheds. Based on the jurisdictional average, several sites stood out: DF012WM, DF013WM, DF015WM in Duffins Creek; RG012bWM, RG013WM in the Rouge River; and HU002WM, HU029WM, HU030WM in the Humber River. These sites were typically better than the jurisdictional average for most indices. Several other sites stood out for having index values which were consistently being worse than the jurisdictional average: MM001WM in Mimico Creek; DN004WM, DN022WM in the Don River; and HL007WM, HL008WM in Highland Creek. In generally, the sites with above average index scores were coldwater (receive input from groundwater) streams in the upper reaches of watersheds with low levels of urbanization (<10%) and relatively high levels of forest (12-40%) in the upstream catchment. Sites with lower than average index scores were located in catchments with high levels of urbanization (63-100%) and low levels of forest cover (<2%). These sites also tend to have anthropogenic modifications, such as concrete lined channels or gabion caging.

Across the jurisdiction, the differences in BMI community were due to changes in the landscape (e.g. % Forest, % Urban) rather than due to differences in habitat (e.g. stream width, depth). Using regression analysis and Canonical Correspondence Analysis (CCA), watershed health was found to be most strongly related to % Urban land cover and Road Density in the upstream catchment. The strong linear relationship suggests that as % Urban Area/Road Density increases, the health of the watershed decreases. Percent Rural land cover, % L3 Cover and % Forest also played a role in structuring the BMI community. The habitat variables tested had only a minor influence on the BMI community composition compared to the broad-scale landscape variables. Other factors such as hydraulic habitat, substrate characteristics, and organic food resources, may account for the remaining variation in the BMI community (e.g. Vinson and Hawkins 1998; Ourso and Frenzel 2003; Lamouroux *et al*. 2004).

Studies in various geographical regions have shown similar relationships between land-use and ecosystem condition (e.g. Freeman and Schorr 2004; Walsh *et al*. 2005; Wang and Kanehl 2003, Stanfield and Kilgour 2006). For example, McBride and Booth (2005) showed that conditions improved when a stream flowed through an intact riparian buffer with forest or wetland vegetation and without road crossings. FBI and Family Richness were the indices most correlated with land-use. The correlation between urban land cover and FBI is similar to that found in other studies (Roy *et al*. 2003; Stepenuck *et al*. 2002; Ourso and Frenzel 2003; Wang and Kanehl 2003; Voelz *et al*. 2005; Schiff and Benoit 2007). Several studies (e.g. Klein 1979, Benke *et al*. 1981, Pratt *et al*. 1981, Duda *et al*. 1982, Jones and Clark 1987, Garie and MacIntosh 1986, Shaver and Maxted 1995, Maxted 1996) also found that diversity (i.e. family richness) decreased as urbanization increased.

Studies have also shown that watershed-scale indicators are more predictive of stream biotic communities than those at the local reach scale (Allan 2004; Potter *et al*. 2005; Roy *et al*. 2005). For example, Booth *et al*. (2002) recommended that maintaining forest cover in watersheds is more important than limiting imperviousness to protect the hydrological properties of streams. In this study, forest cover was the only environmental variable to have a significant logarithmic relationship with the biological indices. The results showed that forest cover levels as low as 5-10% had a considerable positive influence on the health of watersheds.

Watershed health, as determined through the use of BMI, varies significantly across the TRCA region. In general, the Duffins Creek, Rouge River and Humber River watersheds are relatively healthy; Etobicoke Creek, Mimico Creek, Don River and Highland Creek watersheds are less healthy than the average TRCA site. The health of TRCA's watersheds is declining over time. The Humber River, Rouge River, Duffins Creek, Etobicoke Creek and Mimico Creek watersheds all showed declining watershed health over time. The trends in the Don River and Highland Creek were not as clear and their health is likely declining over time but at best, these watersheds are maintaining their already degraded state.

In conclusion, the results of this study have shown that the health of TRCA's watersheds have declined from 2002-2008, a relatively short time period. Increases in urban area and decreases in forest cover have contributed to the decline of watershed health. These rapid changes suggest a need for continued monitoring, particularly in watersheds which are still undergoing the process of urbanization (e.g. Humber River, Rouge River, Duffins Creek).

5. Recommendations

Several recommendations are discussed below which should be considered by the Regional Watershed Monitoring Program for implementation to improve the BMI program.

Collect additional environmental data– Twenty-five (25) different environmental variables were used in the analysis of the benthic invertebrate data. These variables accounted for only 35% of the variation in the BMI community. This may have been because the habitat variables are not collected annually in conjunction with the BMI data. The habitat variables are collected with fish data on a 3-year rotation. Consideration should be given to collecting basic habitat variables (e.g. average stream width and depth) every time a BMI sample is collected. Additional environmental variables such as stream flow and water chemistry are also thought to play a role in structuring the BMI community. Several variables are already collected by the RWMP but at separate sites from the BMI sites. If possible, this data should be modelled for the entire jurisdiction so that the data can be applied to the BMI sites. Other options include creating integrated sentinel sites at which the entire set of variables should be measured simultaneously to allow integration of all aquatic results together. This additional will greatly strengthen TRCA's BMI program.

Switch to OBBN protocol – The Ontario BMI Biomonitoring Network (OBBN) protocol is the accepted protocol for the province of Ontario (Jones *et al*. 2005). The OBBN protocol began after the inception of the RWMP hence the use of a TRCA-specific protocol. Benefits of using the OBBN protocol include:

1. BMI are collected from three transects (rather than 10+) therefore increasing the speed of collection and sorting (and less BMI slaughtered in the name of science!).
2. Because the OBBN protocol is collected from only three transects, there will be less variation in the data collected. Subtle impacts are thought to only be detectable in single habitats or are obscured by variation in multiple habitat sampling (Kerans *et al*. 1992).
3. The OBBN protocol has a standardized time/effort component which is lacking from the TRCA protocol. This means that different crews using the TRCA protocol may use different effort, therefore collecting more/less sample. This could mean that various TRCA samples will inherently have more natural variation (i.e. diversity) caused by additional habitat being sampled which will confound results. This may make the results more difficult to interpret or may mask trends (Kerans *et al*. 1992, Chessman *et al*. 2007)
4. Using the OBBN protocol would allow TRCA data to be easily used by other agencies (e.g. large-scale interpretation). Currently, it has been shown that the OBBN and TRCA protocols produce similar results at the 27-group OBBN identification level (Borisko *et al*. 2007) but has not been shown to produce similar results at lower taxonomic levels(e.g. family/genus/species). Additional work should be completed to show that the data is similar.

Addition of random/targeted/stratified sampling sites – Additional sampling sites could be used to improve geographic coverage across the TRCA's jurisdiction. A random/targeted/stratified sampling component could be added to the program to complement the fixed-station program already in place. The fixed-station program provides an excellent means for looking at trends over time. The addition of extra-sites would allow for greater spatial coverage and could include water features which are not currently sampled as part of the fixed-station program (e.g. headwater streams). A stratified-random design (e.g. by stream size, stream order, etc) would allow for each sub-population to be represented across the jurisdiction.

Addition of BMI sites to complement water quality sampling stations – There are 38 water quality sites throughout the TRCA's jurisdiction. These sites are sampled a minimum of once per month and the samples are investigated for a variety of analytes. Currently, only 15 of the 38 water quality sites have co-located BMI stations. Since water quality is thought to play a large role in shaping the BMI community present at a site, co-located samples would be useful for data analysis and may help tease out which water quality variables are influencing the BMI community.

Database development – A database to store the BMI data is required. There is a plethora of data which should be housed in database within TRCA's corporate database structure. This would allow access to the data by other TRCA employees. The database should have an automated index calculation function to reduce effort and human error.

Improved Quality Assurance/Quality Control – Although a QA/QC program is currently in place, changes could be made to improve it. For example, picking of benthic invertebrates should be completed using at minimum, a magnifying lens rather than strictly naked eye. The "waste" from the junior field staff should be looked at to determine if organisms are being missed. At least 10% of samples (randomly chosen) should be to an outside taxonomist for re-identification. TRCA's staff taxonomist should obtain the North American Benthological Society (NABS) taxonomic certification (http://www.nabstcp.com/).

Development of reference sites/Use RCA for data analysis – The Reference Condition Approach (RCA) compares the benthic community of a potentially stressed ecosystem with that of unstressed reference sites that have similar environmental conditions. The RCA involves creating a predictive model from benthic invertebrate and associated environmental data collected from a large number of reference sites. The model can then be used to tell if the BMI community at the potentially stressed site is different from the reference model. If the test site is different, the conclusion can be drawn that the site is impacted. TRCA is currently collaborating with the Ontario Ministry of the Environment and several other Conservation Authorities in a similar exercise for all of southern Ontario (including Toronto and surrounding area). The RWMP should continue to support this initiative (e.g. supply BMI data for the model, funding) as reference sites from outside the TRCA's jurisdiction are required because all of the TRCA's watersheds are considered impacted from urbanization and cannot be used to develop TRCA-specific reference sites. Once complete, the results from this report should be updated with the new reference values.

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Appendix A – BMI Data

A1. Index Descriptions

Family Richness - Richness measures reflect the diversity of the aquatic assemblage (Resh *et al*. 1995). Increasing diversity correlates with increasing health of the assemblage and suggests that niche space, habitat, and food source are adequate to support survival and propagation of many taxa. The number of taxa (i.e. number of families) is a measure of community composition. Sites with more taxa are generally considered to be in better condition. A high number of families present at a site suggests that habitat and water quality conditions are adequate to support the variable life requirements of benthic invertebrates. Caution should be taken when interpreting this index as the number of taxa can increase with moderate nutrient enrichment, but usually decrease with excessive levels of nutrients, toxic conditions, or physical disturbance of habitat.

Number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) Families - EPT is a short form for Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies). These taxa are generally considered to be sensitive to pollution, and high abundance of these organisms can indicate good environmental conditions. Loss of taxa in these groups is an indication of perturbation (Wallace *et al*. 1996).

Number of Trichoptera Families - The total number of unique Trichoptera (caddisfly) families identified per sample. Trichoptera are a ubiquitous order within the TRCA's jurisdiction. As with other richness measures, increased diversity suggests increased watershed health.

Percent EPT - All three groups (Ephemeroptera, Plecoptera, Trichoptera) require gravel stream bottoms with good concentrations of dissolved oxygen and are typical of high quality stream environments. The presence of these three groups indicates both good water and habitat quality status. For example, stream environments that are impacted by suspended solids will be expected to have a lower % EPT because interstitial spaces in substrate will be filled, thereby reducing suitable habitat for the EPT groups. If there is a high % EPT, it is likely that conditions at the site are better than those sites with a low % EPT.

Percent Chironomidae - Chironomidae (midges) account for most of the invertebrates in many freshwater environments. In streams, they are found in nearly every type of habitat, from small substrates, such as silt/sand, to large substrates, such as cobble. Therefore, their complete absence from a site would be unexpected and provides a clue to potential stream impacts. By comparison, a predominance of midges at a site generally indicates poor water quality. However, it is important to note that there is a wide tolerance range for changes in water quality within the midge family. Nonetheless, a high percentage of midges at a site suggests that stream conditions do not support a "healthy" benthic invertebrate community.

Percent Oligochaeta - Aquatic worms are commonly found in soft sediments rich in organic matter and sites that receive organic pollution. Oligochaeta are considered generally tolerant organisms (e.g. some can tolerate anoxic (no oxygen) conditions). Therefore, worms are often found in relatively higher numbers at sites receiving excessive organic inputs than more oxygen sensitive groups (e.g. stoneflies). A high percentage of Oligochaeta suggests that the site is affected by high organic inputs and as a consequence, low oxygen levels.

Percent Gastropoda - Snails feed by scraping algae and organic debris from leaves, stones and other types of substrates. There are two general types of snails that can be found in freshwater environments: prosobranchs and pulmonates. Since the prosobranchs are derived from marine ancestors, the pulmonates are the type that would be most likely encountered in the field. The pulmonates are descended from terrestrial snails and therefore have lungs and can breathe air by coming to the water's surface to breathe (Pecharsky *et al.* 1990). This enables them to tolerate low dissolved oxygen levels in the water relative to other benthic invertebrates. Careful interpretation of the results using this index is recommended as site specific conditions may also be important. Although snails are generally present at most stream sites in southern Ontario, they are not found in large numbers except when the water velocity is very slow and there is heavy enrichment (*i.e.* organics). Also, snails have specific habitat requirements (*i.e.* substrate for attachment), which may also be important.

Percent Dominant Family - A high percentage of a single group indicates that habitat and water quality conditions are favouring the reproduction of this particular group. This index is often inversely related to Taxa Richness (e.g. number of families) index, particularly when a negative impact is present. A high level of redundancy is equated with the dominance of a pollution tolerant organism and a lowered diversity (Barbour *et al*. 1996). The dominance of any one group at a site represents a concern, particularly if dominated by a group associated with poor stream quality. Again, careful interpretation with this index is necessary.

Simpson's Diversity - Diversity indices provide more information about community composition than simply taxa richness; they also take the relative abundances of different taxa into account. Diversity indices provide important information about community structure (e.g. rarity and commonness of species in a community). The Simpson's Diversity Index is related to the proportion of total organisms contributed by each taxon. Diversity is low when the benthic community is dominated by a few taxa, and higher when the number of organisms is more evenly distributed across numerous taxa. High diversity indicates better environmental conditions, while low values can indicate stresses on the system. The index ranges from 0 which represents no diversity to 1 which represents infinite diversity.

$$Simpson's Diversity = 1 - D$$

$$D = \sum (n/N)^2$$

where:

n = Total number of organisms of a particular taxa (e.g. family)

N = Total number of organisms

Family Biotic Index (FBI) - The Hilsenhoff Biotic Index (Hilsenhoff 1977, 1982, 1987) was originally designed to reflect the nutrient status of streams using species level Arthropoda data. The index has been modified to use higher taxonomic levels (*e.g.* family) (Hilsenhoff 1988) and non-arthropod organisms (Bode *et al*. 1991, Bode *et al*. 1996, Bode *et al*. 2002). Although originally developed to assess low dissolved oxygen caused by organic loading, a purpose for which it works best, the index may also be sensitive to the effects of impoundment, thermal pollution, and some types of chemical pollution (Hilsenhoff 1998, Hooper 1993). FBI values are determined using tolerance (to organic pollution) values which range from 1 to10 and increase as water quality decreases (see table below for families and tolerance values used to calculate FBI for this study). Low values suggest groups which are sensitive to organic pollution while high values suggest groups which are tolerant to organic pollution. Each tolerance value is used in a weighted average calculation with the relative abundance of each benthic group summed into a single value (see table below).

$$FBI = \sum \frac{x_i * t_i}{N}$$

where:
x_i = number of individuals within a taxon
t_i = tolerance value of a taxon
N = total number of organisms in the sample

FBI Value	Rating	Degree of Organic Pollution
0.00 - 3.75	Excellent	Organic pollution unlikely
3.76 - 4.25	Very good	Possible slight organic pollution
4.26 - 5.00	Good	Some organic pollution probable
5.01 - 5.75	Fair	Fairly substantial pollution likely
5.76 - 6.50	Fairly poor	Substantial pollution likely
6.51 - 7.25	Poor	Very substantial pollution likely
7.26 - 10.00	Very poor	Severe organic pollution likely

Kingdom	Phylum	Class	Subclass	Order	Suborder	Family	Family Tolerance
Animalia	Annelida	Clitellata	Hirudinea	Arhynchobdellida	Erpobdelliformes	Erpobdellidae	8
Animalia	Annelida	Clitellata	Hirudinea	Rhynchobdellida	-	Glossiphoniidae	8
Animalia	Annelida	Clitellata	Oligochaeta	-	-	Oligochaeta (Subclass)	10
Animalia	Arthropoda	Arachnida	Acari	-	-	Acari (Subclass)	6
Animalia	Arthropoda	Malacostraca	Eumalacostraca	Decapoda	Pleocyemata	Cambaridae	6
Animalia	Arthropoda	Malacostraca	Eumalacostraca	Amphipoda	Gammaridea	Crangonyctidae	6
Animalia	Arthropoda	Malacostraca	Eumalacostraca	Amphipoda	Gammaridea	Gammaridae	6
Animalia	Arthropoda	Malacostraca	Eumalacostraca	Amphipoda	Gammaridea	Hyalellidae	8
Animalia	Arthropoda	Malacostraca	Eumalacostraca	Amphipoda	Gammaridea	Pontoporeiidae	7
Animalia	Arthropoda	Malacostraca	Eumalacostraca	Isopoda	Asellota	Asellidae	8

Kingdom	Phylum	Class	Subclass	Order	Suborder	Family	Family Tolerance
Animalia	Arthropoda	Ostracoda	-	-	-	Ostracoda (Class)	6
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Adephaga	Carabidae	5
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Adephaga	Dysticidae	5
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Adephaga	Gyrinidae	4
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Adephaga	Haliplidae	5
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Chyrsomelidae	5
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Curculionidae	5
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Dryopidae	5
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Elmidae	5
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Psephenidae	4
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Helophoridae	5
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Hydrophilidae	5
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Hydrachnidae	5
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Hydraenidae	5
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Ptiliidae	5
Animalia	Arthropoda	Insecta	Pterygota	Coleoptera	Polyphaga	Staphylinidae	5
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Dolichopodidae	4
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Empididae	6
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Ephydridae	6
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Muscidae	6
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Sciomyzidae	8
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Syrphidae	10
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Stratiomyidae	7
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Althericidae	4
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Brachycera	Tabanidae	5
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Ceratopogonidae	6
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Chaoboridae	8
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Chironomidae	6
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Culicidae	8
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Dixidae	1
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Simuliidae	6
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Psychodidae	10
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Ptychopteridae	9
Animalia	Arthropoda	Insecta	Pterygota	Diptera	Nematocera	Tipulidae	4
Animalia	Arthropoda	Insecta	Pterygota	Hemiptera	Heteroptera	Corixidae	5
Animalia	Arthropoda	Insecta	Pterygota	Lepidoptera	-	Noctuidae	5
Animalia	Arthropoda	Insecta	Pterygota	Lepidoptera	-	Pyralidae	5

Kingdom	Phylum	Class	Subclass	Order	Suborder	Family	Family Tolerance
Animalia	Arthropoda	Insecta	Pterygota	Plecoptera	Euholognatha	Capniidae	3
Animalia	Arthropoda	Insecta	Pterygota	Plecoptera	Euholognatha	Leuctridae	0
Animalia	Arthropoda	Insecta	Pterygota	Plecoptera	Euholognatha	Nemouridae	2
Animalia	Arthropoda	Insecta	Pterygota	Plecoptera	Euholognatha	Taeniopterygidae	2
Animalia	Arthropoda	Insecta	Pterygota	Plecoptera	Systellognatha	Perlidae	3
Animalia	Arthropoda	Insecta	Pterygota	Plecoptera	Systellognatha	Perlodidae	2
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Glossosomatidae	1
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Dipseudopsidae	5
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Ecnomidae	5
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Hydropsychidae	5
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Polycentropodidae	6
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Psychomyiidae	2
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Hydroptilidae	6
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Leptoceridae	4
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Molannidae	6
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Brachycentridae	2
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Goeridae	3
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Lepidostomatidae	1
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Limnephilidae	4
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Uenoidea	3
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Philopotamidae	4
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Phryganeidae	4
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Rhyacophilidae	1
Animalia	Arthropoda	Insecta	Pterygota	Trichoptera	-	Helicopsychidae	3
Animalia	Arthropoda	Insecta	Pterygota	Megaloptera	-	Corydalidae	4
Animalia	Arthropoda	Insecta	Pterygota	Megaloptera	-	Sialidae	4
Animalia	Arthropoda	Insecta	Pterygota	Ephemeroptera	Furcatergalia	Leptophlebiidae	4
Animalia	Arthropoda	Insecta	Pterygota	Ephemeroptera	Furcatergalia	Caenidae	6
Animalia	Arthropoda	Insecta	Pterygota	Ephemeroptera	Furcatergalia	Ephemerellidae	2
Animalia	Arthropoda	Insecta	Pterygota	Ephemeroptera	Furcatergalia	Leptohyphidae	4
Animalia	Arthropoda	Insecta	Pterygota	Ephemeroptera	Furcatergalia	Ephemeridae	4
Animalia	Arthropoda	Insecta	Pterygota	Ephemeroptera	Furcatergalia	Polymitarcyidae	2
Animalia	Arthropoda	Insecta	Pterygota	Ephemeroptera	Furcatergalia	Potamanthidae	4
Animalia	Arthropoda	Insecta	Pterygota	Ephemeroptera	Pisciforma	Baetidae	6
Animalia	Arthropoda	Insecta	Pterygota	Ephemeroptera	Pisciforma	Siphlonuridae	4
Animalia	Arthropoda	Insecta	Pterygota	Ephemeroptera	Setisura	Heptageniidae	3
Animalia	Arthropoda	Insecta	Pterygota	Ephemeroptera	Setisura	Isonychiidae	2

Kingdom	Phylum	Class	Subclass	Order	Suborder	Family	Family Tolerance
Animalia	Arthropoda	Insecta	Pterygota	Odonata	Anisoptera	Aeshnidae	5
Animalia	Arthropoda	Insecta	Pterygota	Odonata	Anisoptera	Cordulegastridae	8
Animalia	Arthropoda	Insecta	Pterygota	Odonata	Anisoptera	Gomphidae	4
Animalia	Arthropoda	Insecta	Pterygota	Odonata	Anisoptera	Libelluidae	2
Animalia	Arthropoda	Insecta	Pterygota	Odonata	Zygoptera	Calopterygidae	6
Animalia	Arthropoda	Insecta	Pterygota	Odonata	Zygoptera	Coenagrionidae	8
Animalia	Cnidaria	Hydrozoa	Hydroidolina	Anthoathecatae	Capitata	Hydridae	6
Animalia	Mollusca	Bivalvia	Heterodonta	Veneroida	-	Pisidiidae	6
Animalia	Mollusca	Bivalvia	Palaeoheterodonta	Unionoida	-	Unionidae	6
Animalia	Mollusca	Gastropoda	-	Basommatophora	-	Ancylidae	6
Animalia	Mollusca	Gastropoda	-	Basommatophora	-	Lymnaeidae	6
Animalia	Mollusca	Gastropoda	-	Basommatophora	-	Physidae	8
Animalia	Mollusca	Gastropoda	-	Basommatophora	-	Planorbidae	6
Animalia	Mollusca	Gastropoda	-	Heterostropha	-	Valvatidae	8
Animalia	Mollusca	Gastropoda	-	Neotaenioglossa	-	Hydrobiidae	8
Animalia	Mollusca	Gastropoda	-	Neotaenioglossa	-	Pleuroceridae	6
Animalia	Mollusca	Gastropoda	Prosobranchia	Mesogastropoda	-	Pomatiopsidae	6
Animalia	Platyhelminthes	Turbellaria	Archoophora	Proseriata	-	Plagiostomidae	6
Animalia	Platyhelminthes	Turbellaria	Archoophora	Tricladida	-	Planariidae	6
Animalia	Platyhelminthes	Turbellaria	Archoophora	Tricladida	-	Tricladida (Order)	6

A2. Benthic invertebrate family list for all TRCA RWMP sites (2001-2008)

Kingdom	Phylum	Class	Order	Family
Animalia	Annelida	Clitellata	Arhynchobdellida	Erpobdellidae
Animalia	Annelida	Clitellata	Rhynchobdellida	Glossiphoniidae
Animalia	Annelida	Clitellata	-	-
Animalia	Arthropoda	Arachnida	-	-
Animalia	Arthropoda	Malacostraca	Decapoda	Cambaridae
Animalia	Arthropoda	Malacostraca	Amphipoda	Crangonyctidae
Animalia	Arthropoda	Malacostraca	Amphipoda	Gammaridae
Animalia	Arthropoda	Malacostraca	Amphipoda	Hyalellidae
Animalia	Arthropoda	Malacostraca	Amphipoda	Pontoporeiidae
Animalia	Arthropoda	Malacostraca	Isopoda	Asellidae
Animalia	Arthropoda	Ostracoda	-	-
Animalia	Arthropoda	Insecta	Coleoptera	Dysticidae
Animalia	Arthropoda	Insecta	Coleoptera	Gyrinidae
Animalia	Arthropoda	Insecta	Coleoptera	Haliplidae
Animalia	Arthropoda	Insecta	Coleoptera	Chyrsomelidae
Animalia	Arthropoda	Insecta	Coleoptera	Curculionidae
Animalia	Arthropoda	Insecta	Coleoptera	Anthicidae
Animalia	Arthropoda	Insecta	Coleoptera	Tenebrionidae
Animalia	Arthropoda	Insecta	Coleoptera	Dryopidae
Animalia	Arthropoda	Insecta	Coleoptera	Elmidae
Animalia	Arthropoda	Insecta	Coleoptera	Psephenidae
Animalia	Arthropoda	Insecta	Coleoptera	Hydrophilidae
Animalia	Arthropoda	Insecta	Coleoptera	Hydrachnidae
Animalia	Arthropoda	Insecta	Coleoptera	Hydraenidae
Animalia	Arthropoda	Insecta	Coleoptera	Ptiliidae
Animalia	Arthropoda	Insecta	Coleoptera	Sparganophilidae
Animalia	Arthropoda	Insecta	Coleoptera	Staphylinidae
Animalia	Arthropoda	Insecta	Diptera	Dolichopodidae
Animalia	Arthropoda	Insecta	Diptera	Empididae
Animalia	Arthropoda	Insecta	Diptera	Ephydridae
Animalia	Arthropoda	Insecta	Diptera	Muscidae
Animalia	Arthropoda	Insecta	Diptera	Sciomyzidae
Animalia	Arthropoda	Insecta	Diptera	Syrphidae
Animalia	Arthropoda	Insecta	Diptera	Stratiomyidae
Animalia	Arthropoda	Insecta	Diptera	Althericidae
Animalia	Arthropoda	Insecta	Diptera	Tabanidae
Animalia	Arthropoda	Insecta	Diptera	Ceratopogonidae
Animalia	Arthropoda	Insecta	Diptera	Chaoboridae

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Diptera	Chironomidae
Animalia	Arthropoda	Insecta	Diptera	Culicidae
Animalia	Arthropoda	Insecta	Diptera	Dixidae
Animalia	Arthropoda	Insecta	Diptera	Simuliidae
Animalia	Arthropoda	Insecta	Diptera	Psychodidae
Animalia	Arthropoda	Insecta	Diptera	Ptychopteridae
Animalia	Arthropoda	Insecta	Diptera	Tipulidae
Animalia	Arthropoda	Insecta	Hemiptera	Corixidae
Animalia	Arthropoda	Insecta	Hemiptera	Belostomatidae
Animalia	Arthropoda	Insecta	Hemiptera	Pleidae
Animalia	Arthropoda	Insecta	Lepidoptera	Crambidae
Animalia	Arthropoda	Insecta	Lepidoptera	Pyralidae
Animalia	Arthropoda	Insecta	Plecoptera	Capniidae
Animalia	Arthropoda	Insecta	Plecoptera	Leuctridae
Animalia	Arthropoda	Insecta	Plecoptera	Nemouridae
Animalia	Arthropoda	Insecta	Plecoptera	Taeniopterygidae
Animalia	Arthropoda	Insecta	Plecoptera	Perlidae
Animalia	Arthropoda	Insecta	Plecoptera	Perlodidae
Animalia	Arthropoda	Insecta	Trichoptera	Glossosomatidae
Animalia	Arthropoda	Insecta	Trichoptera	Dipseudopsidae
Animalia	Arthropoda	Insecta	Trichoptera	Ecnomidae
Animalia	Arthropoda	Insecta	Trichoptera	Hydropsychidae
Animalia	Arthropoda	Insecta	Trichoptera	Polycentropodidae
Animalia	Arthropoda	Insecta	Trichoptera	Psychomyiidae
Animalia	Arthropoda	Insecta	Trichoptera	Hydroptilidae
Animalia	Arthropoda	Insecta	Trichoptera	Leptoceridae
Animalia	Arthropoda	Insecta	Trichoptera	Mideopsidae
Animalia	Arthropoda	Insecta	Trichoptera	Molannidae
Animalia	Arthropoda	Insecta	Trichoptera	Brachycentridae
Animalia	Arthropoda	Insecta	Trichoptera	Goeridae
Animalia	Arthropoda	Insecta	Trichoptera	Lepidostomatidae
Animalia	Arthropoda	Insecta	Trichoptera	Limnephilidae
Animalia	Arthropoda	Insecta	Trichoptera	Uenoidea
Animalia	Arthropoda	Insecta	Trichoptera	Philopotamidae
Animalia	Arthropoda	Insecta	Trichoptera	Phryganeidae
Animalia	Arthropoda	Insecta	Trichoptera	Rhyacophilidae
Animalia	Arthropoda	Insecta	Trichoptera	Helicopsychidae
Animalia	Arthropoda	Insecta	Megaloptera	Corydalidae
Animalia	Arthropoda	Insecta	Megaloptera	Sialidae
Animalia	Arthropoda	Insecta	Ephemeroptera	Leptophlebiidae

Kingdom	Phylum	Class	Order	Family
Animalia	Arthropoda	Insecta	Ephemeroptera	Caenidae
Animalia	Arthropoda	Insecta	Ephemeroptera	Ephemerellidae
Animalia	Arthropoda	Insecta	Ephemeroptera	Leptohyphidae
Animalia	Arthropoda	Insecta	Ephemeroptera	Ephemeridae
Animalia	Arthropoda	Insecta	Ephemeroptera	Polymitarcyidae
Animalia	Arthropoda	Insecta	Ephemeroptera	Potamanthidae
Animalia	Arthropoda	Insecta	Ephemeroptera	Baetidae
Animalia	Arthropoda	Insecta	Ephemeroptera	Siphlonuridae
Animalia	Arthropoda	Insecta	Ephemeroptera	Heptageniidae
Animalia	Arthropoda	Insecta	Ephemeroptera	Isonychiidae
Animalia	Arthropoda	Insecta	Odonata	Aeshnidae
Animalia	Arthropoda	Insecta	Odonata	Cordulegastridae
Animalia	Arthropoda	Insecta	Odonata	Gomphidae
Animalia	Arthropoda	Insecta	Odonata	Libelluidae
Animalia	Arthropoda	Insecta	Odonata	Calopterygidae
Animalia	Arthropoda	Insecta	Odonata	Coenagrionidae
Animalia	Cnidaria	Hydrozoa	Anthoathecatae	Hydridae
Animalia	Mollusca	Bivalvia	Veneroida	Pisidiidae
Animalia	Mollusca	Bivalvia	Unionoida	Unionidae
Animalia	Mollusca	Gastropoda	Basommatophora	Ancylidae
Animalia	Mollusca	Gastropoda	Basommatophora	Lymnaeidae
Animalia	Mollusca	Gastropoda	Basommatophora	Physidae
Animalia	Mollusca	Gastropoda	Basommatophora	Planorbidae
Animalia	Mollusca	Gastropoda	Heterostropha	Valvatidae
Animalia	Mollusca	Gastropoda	Neotaenioglossa	Hydrobiidae
Animalia	Mollusca	Gastropoda	Neotaenioglossa	Pleuroceridae
Animalia	Mollusca	Gastropoda	Mesogastropoda	Pomatiopsidae
Animalia	Nemata	-	-	-
Animalia	Nemertea	Enopla	Hoplonemertea	Tetrastemmatidae
Animalia	Platyhelminthes	Turbellaria	Tricladida	Planariidae
Animalia	Platyhelminthes	Turbellaria	Tricladida	-

A3. Jurisdictional BMI index values by year

Index	Year	Average	Std Dev	N
# EPT Families	2001	2	2	96
	2002	3	2	133
	2003	3	2	138
	2004	3	2	126
	2005	3	2	141
	2006	3	2	140
	2007	2	2	144
	2008	3	2	130
# Families	2001	8	3	96
	2002	13	4	131
	2003	11	4	139
	2004	10	4	126
	2005	10	4	140
	2006	11	4	140
	2007	10	4	143
	2008	10	4	130
# Trichoptera Families	2001	1	1	96
	2002	2	1	131
	2003	1	1	139
	2004	1	1	126
	2005	1	1	140
	2006	1	1	140
	2007	1	1	143
	2008	1	1	130
% Chironomidae	2001	44	24	96
	2002	30	18	131
	2003	30	18	139
	2004	26	20	126
	2005	43	21	140
	2006	39	21	140
	2007	45	22	143
	2008	37	20	130
% Dominant Family	2001	54.40	19.72	96
	2002	40.97	16.12	133
	2003	44.85	15.80	138
	2004	48.19	16.95	126
	2005	50.70	15.11	141
	2006	48.72	17.30	140
	2007	52.55	17.44	144
	2008	47.60	17.28	130

Index	Year	Average	Std Dev	N
% EPT	2001	19	19	96
	2002	20	17	131
	2003	22	20	139
	2004	23	20	126
	2005	15	16	140
	2006	17	17	140
	2007	14	16	143
	2008	21	20	130
% Gastropoda	2001	2	5	96
	2002	4	6	131
	2003	2	5	139
	2004	1	2	126
	2005	1	2	140
	2006	2	5	140
	2007	1	2	143
	2008	1	1	130
% Oligochaeta	2001	11	20	96
	2002	10	15	131
	2003	11	16	139
	2004	12	18	126
	2005	14	16	140
	2006	14	18	140
	2007	15	18	143
FBI	2001	6.33	1.01	96
	2002	6.27	0.90	131
	2003	6.37	0.92	139
	2004	6.43	1.05	126
	2005	6.54	0.87	140
	2006	6.54	0.88	140
	2007	6.56	0.83	143
	2008	6.47	0.95	130
Simpson's Diversity	2001	0.60	0.20	96
	2002	0.73	0.14	131
	2003	0.70	0.14	139
	2004	0.66	0.17	126
	2005	0.65	0.14	140
	2006	0.66	0.16	140
	2007	0.62	0.17	143
	2008	0.67	0.16	130

A4. Average BMI index values by site

		Average										Standard Deviation									
Station	N	# EPT Families	Family Richness	# Trichoptera Families	% Chironomidae	% EPT	% Gastropoda	% Oligochaeta	% Dominant Family	FBI	Simpson's Diversity	# EPT Families	Family Richness	# Trichoptera Families	% Chironomidae	% EPT	% Gastropoda	% Oligochaeta	% Dominant Family	FBI	Simpson's Diversity
CC001WM	7	1	10	0	19	1	1	8	43	6.81	0.71	1	4	0	13	1	1	8	16	0.58	0.14
CC002WM	7	1	11	1	23	2	0	6	38	6.28	0.76	1	2	1	15	2	0	6	12	0.34	0.07
CC003WM	7	2	12	1	29	10	1	3	36	6.36	0.76	0	3	0	11	12	3	3	4	0.30	0.05
DF001WM	7	3	9	1	58	9	0	20	60	6.65	0.55	2	4	1	22	10	0	16	20	0.68	0.22
DF002WM	7	2	9	1	22	17	0	12	46	7.09	0.69	1	2	1	20	25	0	15	11	0.82	0.09
DF003WM	7	5	12	2	28	26	1	3	36	5.27	0.79	2	2	1	9	9	2	3	7	0.22	0.04
DF004WM	7	7	17	3	41	27	4	3	42	5.59	0.76	1	2	1	17	15	4	3	14	0.51	0.10
DF005WM	7	3	12	2	32	17	1	3	35	5.68	0.78	1	2	1	10	11	2	3	8	0.23	0.05
DF006WM	7	4	11	1	29	36	1	6	33	5.58	0.79	1	2	0	16	15	2	6	12	0.54	0.08
DF007WM	7	5	13	3	49	28	2	1	49	5.61	0.67	2	1	1	20	18	3	1	20	0.37	0.15
DF008WM	7	5	15	3	29	32	6	1	32	5.76	0.80	2	5	1	14	7	7	2	8	0.19	0.07
DF009WM	7	5	15	2	26	32	3	8	33	5.54	0.81	1	2	1	16	17	5	10	10	0.77	0.05
DF010WM	7	5	13	2	38	31	0	2	42	5.45	0.72	2	2	1	24	18	0	2	20	0.40	0.15
DF011WM	7	3	12	1	35	23	7	13	40	6.08	0.73	2	4	1	13	23	11	12	15	0.83	0.11
DF012WM	6	7	14	3	38	31	0	2	38	5.40	0.78	2	3	1	9	11	1	2	9	0.24	0.05
DF013WM	6	6	12	3	28	28	3	2	30	5.49	0.80	2	4	1	7	15	3	3	6	0.26	0.05
DF014WM	6	2	12	1	31	10	0	9	45	6.69	0.72	1	2	1	18	10	1	11	8	0.62	0.06
DF015WM	6	7	16	3	26	26	2	1	34	5.36	0.81	2	3	1	17	7	3	1	8	0.21	0.05
DF016WM	7	3	13	1	55	14	2	1	57	5.76	0.62	1	3	1	21	8	2	1	17	0.16	0.15
DF017WM	6	2	9	2	24	12	0	2	49	5.91	0.64	2	4	1	16	12	1	2	20	0.15	0.20
DF018WM	7	3	10	1	42	15	0	14	46	6.45	0.68	1	3	0	19	15	0	15	16	0.68	0.12
DF019WM	7	4	11	2	35	20	2	6	42	5.90	0.74	1	2	1	12	12	2	4	4	0.39	0.05
DF020WMb	6	5	15	2	42	23	1	3	42	5.58	0.74	1	4	1	17	9	1	3	17	0.38	0.14
DF021WM	5	4	9	2	8	20	0	0	59	5.80	0.53	2	1	2	9	10	0	0	19	0.10	0.15
DN001WM	7	1	4	0	17	2	0	77	77	9.14	0.31	1	2	0	17	3	0	22	22	0.82	0.24
DN002WM	6	3	8	2	32	43	0	20	46	6.74	0.67	1	1	1	16	23	1	11	11	0.53	0.06
DN003WM	8	1	6	0	55	23	0	18	62	6.74	0.50	1	2	1	24	23	1	11	17	0.45	0.17
DN004WM	7	1	4	0	21	3	2	73	73	8.92	0.40	1	1	0	8	4	4	12	12	0.47	0.15
DN005WM	7	3	10	2	27	24	2	30	40	7.33	0.73	1	2	1	17	21	2	11	7	0.60	0.06
DN006WMb	5	2	9	1	37	6	1	33	48	7.53	0.65	1	2	1	26	6	2	16	18	0.74	0.15
DN007WM	6	2	7	1	18	24	1	6	51	7.15	0.61	0	2	0	13	12	1	5	19	0.41	0.16
DN008WM	6	3	7	2	32	20	0	32	50	7.42	0.66	1	1	1	23	17	0	17	12	0.91	0.10
DN009WM	4	2	8	1	40	16	1	23	49	7.17	0.66	0	1	1	29	19	3	11	19	0.54	0.16
DN010WM	4	2	10	1	22	42	1	3	44	5.94	0.69	1	2	0	8	22	1	2	20	0.03	0.17
DN011WM	8	2	9	1	23	33	2	26	44	7.03	0.70	1	3	1	12	19	4	21	15	0.93	0.13
DN012WM	7	2	8	1	23	37	1	19	36	6.98	0.75	0	2	0	15	10	2	11	5	0.50	0.04
DN013WM	7	2	7	1	17	66	0	12	59	6.36	0.57	1	3	1	8	24	1	18	18	0.78	0.20
DN014WM	5	2	8	1	49	15	1	17	49	6.90	0.66	1	2	1	12	8	2	16	12	0.53	0.11
DN015WM	7	2	8	1	3	50	2	17	40	7.06	0.72	0	1	0	1	14	2	9	10	0.43	0.05
DN016WM	8	2	10	1	23	31	1	22	36	7.12	0.76	1	3	1	12	16	1	19	14	0.68	0.11
DN017WM	8	1	7	0	33	4	6	41	51	7.97	0.62	1	3	1	18	4	9	22	16	0.78	0.14
DN018WM	7	1	9	1	48	5	0	30	53	7.05	0.62	1	3	1	18	6	1	17	12	0.69	0.11
DN019WM	8	1	9	0	19	1	2	42	49	8.23	0.63	1	3	0	13	2	2	21	16	0.77	0.13
DN020WM	7	2	8	1	20	14	0	29	51	7.73	0.64	1	2	1	15	16	0	24	13	0.80	0.10
DN021WM	8	2	10	1	22	39	1	9	35	6.10	0.77	0	2	0	18	18	2	8	10	0.32	0.06
DN022WM	6	1	7	0	55	3	2	32	66	7.28	0.48	1	2	1	27	5	3	24	17	0.89	0.18
DN023WM	8	2	10	1	30	27	1	19	36	6.87	0.77	1	3	0	11	16	2	12	6	0.52	0.05
EC001WM	8	1	8	0	37	6	2	16	54	7.19	0.62	1	1	1	27	7	3	14	13	0.49	0.13

		Average										Standard Deviation									
Station	N	# EPT Families	Family Richness	# Trichoptera Families	% Chironomidae	% EPT	% Gastropoda	% Oligochaeta	% Dominant Family	FBI	Simpson's Diversity	# EPT Families	Family Richness	# Trichoptera Families	% Chironomidae	% EPT	% Gastropoda	% Oligochaeta	% Dominant Family	FBI	Simpson's Diversity
EC002WM	6	3	8	2	26	19	0	6	54	6.99	0.61	1	1	1	29	8	0	6	18	0.47	0.16
EC003WM	8	0	4	0	5	0	0	1	86	7.77	0.22	0	2	0	5	0	0	2	12	0.25	0.17
EC004WM	8	3	9	1	27	17	3	7	48	7.10	0.68	1	2	1	15	7	6	9	13	0.38	0.09
EC005WM	7	3	10	2	44	16	3	11	50	6.87	0.63	1	2	1	25	15	5	10	17	0.43	0.14
EC006WM	8	3	9	1	64	13	7	6	65	6.32	0.48	1	2	0	26	15	14	14	24	0.58	0.26
EC007WM	7	3	13	2	37	18	7	10	47	6.63	0.69	1	3	1	23	15	11	7	19	0.63	0.15
EC008WM	8	4	12	2	37	20	1	5	40	6.03	0.74	1	2	1	20	16	2	6	17	0.37	0.14
EC009WM	7	3	9	1	49	7	0	16	58	7.06	0.57	1	3	1	24	7	1	14	19	0.53	0.16
EC010WM	6	2	10	1	38	3	2	15	40	6.65	0.71	1	3	1	8	3	3	8	7	0.51	0.09
EC011WM	6	3	11	1	44	18	1	12	45	6.41	0.71	1	2	1	19	8	2	11	18	0.60	0.15
EC012WM	8	3	15	1	43	7	7	3	47	6.26	0.72	1	4	1	19	4	10	1	16	0.37	0.15
EC013WM	7	2	14	1	46	4	3	6	46	6.29	0.72	2	3	1	17	5	2	4	16	0.27	0.12
EC014WM	7	1	12	0	38	2	9	14	39	6.59	0.74	1	3	0	20	2	10	13	16	0.53	0.12
FB001WM	6	1	9	1	43	4	1	5	58	6.93	0.57	1	3	1	25	4	1	3	17	0.49	0.16
FB002WM	5	1	6	0	48	1	1	13	74	7.22	0.40	1	1	0	35	1	1	15	15	0.59	0.18
FB003WM	6	1	9	0	40	2	1	27	54	7.63	0.61	1	4	1	22	3	2	24	8	0.88	0.08
FB004WM	5	0	5	0	62	0	5	29	74	7.28	0.37	1	3	0	31	1	7	32	18	1.27	0.20
HL001WM	6	0	8	0	19	0	0	25	42	7.30	0.73	0	1	0	15	0	1	17	12	0.52	0.08
HL002WM	6	2	7	1	58	21	0	11	67	6.49	0.49	1	2	0	28	25	0	9	17	0.48	0.21
HL003WM	8	2	8	1	51	16	1	15	51	6.86	0.63	1	3	0	18	15	1	8	18	0.30	0.16
HL004WM	6	2	8	1	53	19	2	14	53	6.73	0.63	1	2	1	2	14	2	10	2	0.37	0.04
HL005WM	7	2	7	1	58	15	0	9	65	6.67	0.50	1	1	1	27	22	1	7	16	0.44	0.16
HL006WM	7	1	7	0	30	8	4	48	61	8.15	0.53	1	3	0	22	8	6	32	21	1.13	0.21
HL007WM	8	0	4	0	63	3	4	26	68	7.15	0.43	1	1	1	21	9	9	25	15	0.92	0.16
HL008WM	7	0	4	0	67	0	1	28	74	7.10	0.36	0	2	0	25	1	3	27	15	1.11	0.14
HL009WM	7	1	4	0	23	13	0	56	62	8.24	0.51	0	1	0	11	10	0	24	10	0.97	0.09
HL010WM	8	3	9	2	26	28	0	20	45	7.05	0.71	1	1	1	19	19	0	15	9	0.62	0.06
HL011WM	8	1	7	1	54	3	0	29	64	7.20	0.50	1	2	1	24	5	0	25	14	0.98	0.15
HU001WM	8	4	11	2	53	21	0	8	53	5.98	0.66	1	2	1	13	10	1	9	13	0.44	0.11
HU002WM	8	6	15	2	21	20	1	23	36	6.42	0.80	1	3	1	14	10	1	19	8	0.91	0.06
HU003WM	7	3	11	2	38	26	2	10	45	6.29	0.71	1	3	1	17	18	3	11	13	0.46	0.11
HU004WM	8	3	9	2	25	21	1	14	44	6.76	0.72	1	2	0	21	13	2	14	8	0.48	0.06
HU005WM	8	3	9	2	43	45	3	3	61	6.14	0.55	1	3	1	24	24	5	2	13	0.15	0.13
HU006WM	8	2	9	1	16	27	1	48	56	7.94	0.59	0	2	0	7	24	2	25	17	1.02	0.16
HU007WM	8	5	13	2	33	42	2	5	42	5.77	0.73	1	4	0	11	16	2	5	14	0.34	0.13
HU008WM	7	1	7	0	62	10	0	21	63	6.73	0.52	1	1	1	16	7	0	14	13	0.67	0.13
HU009WM	7	4	11	1	39	33	1	2	44	5.88	0.73	1	2	0	18	13	2	3	12	0.18	0.08
HU010WM	8	4	12	1	27	46	1	8	48	5.67	0.68	2	4	0	17	24	1	9	19	0.56	0.18
HU011WM	8	3	12	1	32	41	5	6	41	6.01	0.73	2	4	1	15	18	3	10	15	0.41	0.12
HU012WM	8	5	12	1	26	33	1	6	37	5.50	0.77	2	2	1	13	22	1	10	9	0.59	0.04
HU013WM	7	4	11	1	50	23	5	9	51	6.12	0.66	2	3	1	23	14	8	6	20	0.34	0.20
HU014WM	8	4	14	1	24	18	2	9	38	6.04	0.77	1	3	1	13	11	2	14	10	0.66	0.07
HU015WM	7	4	13	1	40	29	1	2	46	5.68	0.71	2	4	1	20	22	1	3	15	0.28	0.14
HU016WM	7	4	13	3	36	27	6	6	37	6.03	0.78	2	3	1	13	9	5	4	13	0.25	0.08
HU017WM	7	0	11	0	44	0	3	7	46	6.10	0.70	0	4	0	17	0	4	10	15	0.58	0.13
HU018WM	6	2	8	1	63	4	2	7	68	6.20	0.48	1	2	1	26	4	2	6	17	0.32	0.19
HU019WM	6	2	11	0	46	5	3	18	46	6.71	0.71	1	2	1	13	6	3	9	12	0.44	0.07
HU020WM	7	2	8	1	51	12	1	21	57	6.73	0.56	1	4	1	28	10	2	19	21	0.85	0.22
HU021WM	7	4	14	1	49	13	4	6	53	6.06	0.63	2	5	1	26	11	4	4	24	0.18	0.25
HU022WM	8	4	14	2	30	15	7	15	42	6.71	0.74	1	4	1	17	10	11	13	15	0.65	0.12
HU023WM	8	3	15	1	40	11	4	14	41	6.31	0.74	2	5	1	21	8	4	5	20	0.31	0.15

Station	N	Average										Standard Deviation									
		# EPT Families	Family Richness	# Trichoptera Families	% Chironomidae	% EPT	% Gastropoda	% Oligochaeta	% Dominant Family	FBI	Simpson's Diversity	# EPT Families	Family Richness	# Trichoptera Families	% Chironomidae	% EPT	% Gastropoda	% Oligochaeta	% Dominant Family	FBI	Simpson's Diversity
HU024WM	8	2	9	1	40	9	1	31	51	7.02	0.66	1	2	1	21	9	1	18	14	0.78	0.11
HU025WM	7	1	10	0	25	4	2	1	43	5.76	0.71	1	3	1	14	5	2	1	11	0.16	0.08
HU026WM	8	4	12	2	47	18	0	16	47	6.34	0.69	1	4	1	12	11	1	14	12	0.71	0.11
HU027WM	7	4	11	2	62	10	1	12	62	6.27	0.57	2	3	1	11	5	2	10	11	0.40	0.11
HU028WM	8	2	11	1	28	13	2	27	44	6.80	0.71	2	3	1	12	11	4	25	15	1.14	0.12
HU029WM	8	7	14	3	23	40	1	2	39	5.19	0.78	2	3	1	17	16	1	2	9	0.34	0.05
HU030WM	7	6	15	3	24	44	0	3	33	5.30	0.80	2	3	1	12	21	0	6	9	0.54	0.07
HU031WM	8	2	11	1	42	10	2	17	57	6.70	0.58	1	3	1	31	10	2	29	25	1.17	0.26
HU032WM	6	1	12	1	36	9	9	5	42	6.61	0.75	1	4	1	20	9	17	4	13	0.38	0.13
HU033WM	8	3	13	2	40	23	2	2	44	5.50	0.71	1	3	1	16	12	3	2	12	0.23	0.08
HU034WM	7	4	13	2	32	28	0	2	37	5.51	0.74	1	4	1	23	16	0	4	19	0.32	0.18
HU035WM	7	3	14	2	50	14	2	2	51	5.63	0.67	1	2	1	17	6	4	2	15	0.21	0.11
HU036WM	8	5	13	2	29	36	0	2	37	5.48	0.77	1	3	1	12	9	0	2	6	0.26	0.04
HU037WM	7	5	12	2	35	21	0	7	48	5.75	0.64	3	4	1	27	21	0	11	23	0.74	0.18
HU038WM	8	6	13	3	34	33	1	1	38	5.37	0.75	2	2	1	17	16	1	2	14	0.50	0.09
MM001WM	7	0	7	0	36	0	0	35	64	7.77	0.54	1	4	0	28	1	0	31	10	1.11	0.12
MM002WM	7	2	8	1	20	27	0	10	50	7.19	0.64	1	2	1	15	21	0	6	18	0.45	0.15
MM003WM	7	1	8	1	36	15	4	16	50	7.12	0.60	1	2	1	29	19	9	19	19	0.74	0.18
MM004WM	7	1	6	0	44	7	0	14	56	7.13	0.59	1	2	0	23	15	0	8	14	0.32	0.12
MM005WM	6	1	8	1	55	6	1	21	57	7.10	0.55	1	4	1	24	4	2	20	22	0.83	0.26
PT001WM	7	2	8	1	24	5	0	2	56	6.18	0.61	1	1	0	22	4	0	2	9	0.32	0.07
PT002WM	6	1	7	0	60	2	1	2	65	6.55	0.50	1	4	1	20	4	2	3	14	0.43	0.19
PT004WM	4	2	11	1	13	2	2	3	65	7.17	0.50	1	1	1	16	1	1	2	24	0.80	0.26
RG001WM	7	5	14	2	38	36	0	5	45	5.86	0.73	1	2	1	17	18	0	4	10	0.16	0.07
RG002WM	8	4	12	2	23	53	1	2	42	5.80	0.73	1	2	1	7	16	2	1	13	0.22	0.10
RG003WM	7	2	9	1	25	59	2	8	53	6.27	0.63	1	2	1	11	8	4	6	11	0.25	0.09
RG004WM	7	3	13	2	47	18	3	8	49	6.28	0.67	1	3	1	25	14	4	7	21	0.31	0.20
RG005WM	7	2	8	1	63	15	0	11	63	6.35	0.55	1	2	1	14	15	0	8	14	0.36	0.17
RG006WM	8	4	12	2	40	30	1	6	41	5.98	0.74	1	1	1	13	15	3	8	12	0.43	0.08
RG007WM	8	5	17	2	27	30	5	3	33	5.71	0.83	1	3	1	15	14	6	5	10	0.36	0.05
RG008WM	6	1	9	1	45	1	1	15	47	6.65	0.67	1	1	1	18	2	1	11	17	0.56	0.12
RG009WM	8	2	9	1	51	6	1	15	58	6.78	0.60	1	3	0	21	5	2	15	14	0.69	0.15
RG010WM	8	2	11	1	43	29	3	3	44	6.22	0.70	1	1	1	18	11	6	3	16	0.31	0.13
RG011WM	7	4	13	1	28	24	4	3	40	5.77	0.75	1	3	0	24	19	7	3	12	0.27	0.09
RG012WMb	6	5	14	3	36	37	0	1	36	5.38	0.77	1	3	1	12	9	0	1	8	0.25	0.04
RG013WM	7	6	16	2	20	35	1	1	37	5.25	0.79	2	4	1	7	21	1	2	10	0.26	0.07
RG014WM	7	5	14	3	34	15	2	3	39	5.71	0.76	2	4	1	14	11	3	2	11	0.34	0.08
RG015WM	8	4	14	2	22	23	3	3	40	5.63	0.77	1	3	1	17	10	4	3	9	0.23	0.06
RG016WM	8	4	15	1	39	9	3	5	40	5.96	0.76	1	3	1	13	7	2	4	12	0.34	0.07
RG017WM	8	2	12	1	34	5	7	3	38	6.10	0.75	1	2	1	14	6	11	4	9	0.36	0.07
RG018WM	8	2	11	1	53	7	2	2	53	6.01	0.66	2	3	1	13	6	2	2	13	0.17	0.12
RG019WM	8	2	11	1	40	4	1	6	43	5.92	0.73	1	3	1	17	4	3	5	11	0.30	0.06
RG020WM	8	2	10	1	53	5	1	16	53	6.51	0.62	1	4	1	21	6	1	11	22	0.45	0.20
RG021WM	8	2	11	1	36	16	2	10	42	6.26	0.74	1	2	1	19	11	2	10	12	0.55	0.08
RG022WM	8	3	11	2	41	22	1	5	42	5.74	0.71	1	4	1	18	10	1	10	18	0.53	0.14
RG023WM	8	4	12	1	48	23	1	3	49	5.62	0.65	2	4	1	24	16	1	3	24	0.26	0.22
RG024WM	8	3	11	2	29	17	2	20	37	6.69	0.76	1	2	1	13	9	2	13	11	0.59	0.07
RG025WM	7	4	12	2	60	16	1	1	60	5.54	0.58	3	3	2	18	11	2	1	18	0.37	0.17
RG026WM	8	5	13	3	52	23	1	3	52	5.42	0.67	1	4	1	17	9	1	5	17	0.58	0.16

A5. Linear Regression Results

Environmental Variable	Index	Trend	R^2	F	p
% Urban	% EPT	↓	0.032	4.004	0.0476
	% Gastropoda	↑	0.002	0.185	0.6680
	% Oligochaeta	↑	0.196	29.920	< 0.0001
	% Chironomidae	↑	0.032	4.093	0.0452
	Family Richness	↓	0.424	90.476	< 0.0001
	# Trichoptera Families	↓	0.199	30.620	< 0.0001
	# EPT Families	↓	0.309	54.900	< 0.0001
	% Dominant Family	↑	0.171	25.419	< 0.0001
	Simpson's Diversity	↓	0.215	33.677	< 0.0001
	FBI	↑	0.439	96.171	< 0.0001
% Urbanizing	% EPT	↑	0.001	0.084	0.7723
	% Gastropoda	↓	0.009	1.146	0.2864
	% Oligochaeta	↑	0.003	0.309	0.5795
	% Chironomidae	↑	0.011	1.317	0.2533
	Family Richness	↑	0.013	1.600	0.2083
	# Trichoptera Families	↑	0.002	0.287	0.5930
	# EPT Families	↑	0.001	0.122	0.7272
	% Dominant Family	↓	0.007	0.927	0.3376
	Simpson's Diversity	↑	0.010	1.274	0.2612
	FBI	↓	0.012	1.491	0.2244
% Rural	% EPT	↑	0.035	4.406	0.0379
	% Gastropoda	↓	0.007	0.827	0.3649
	% Oligochaeta	↓	0.172	25.482	< 0.0001
	% Chironomidae	↓	0.050	6.492	0.0121
	Family Richness	↑	0.351	66.501	< 0.0001
	# Trichoptera Families	↑	0.175	26.040	< 0.0001
	# EPT Families	↑	0.284	48.900	< 0.0001
	% Dominant Family	↑	0.137	19.581	< 0.0001
	Simpson's Diversity	↑	0.171	25.308	< 0.0001
	FBI	↓	0.365	70.787	< 0.0001
% Beach/Bluff	% EPT	↓	0.011	1.374	0.2434
	% Gastropoda	↓	0.008	0.936	0.3352
	% Oligochaeta	↓	0.007	0.926	0.3377
	% Chironomidae	↑	0.001	0.077	0.7825
	Family Richness	↓	0.001	0.127	0.7226
	# Trichoptera Families	↑	0.000	0.020	0.8878

Environmental Variable	Index	Trend	R^2	F	p
	# EPT Families	↓	0.008	1.021	0.3142
	% Dominant Family	↑	0.007	0.904	0.3436
	Simpson's Diversity	↓	0.007	0.878	0.3507
	FBI	↑	0.019	2.353	0.1276
% Forest	% EPT	↑	0.045	5.770	0.0178
	% Gastropoda	↓	0.010	1.208	0.2740
	% Oligochaeta	↓	0.147	21.176	< 0.0001
	% Chironomidae	↓	0.055	7.166	0.0084
	Family Richness	↑	0.150	21.786	< 0.0001
	# Trichoptera Families	↑	0.081	10.824	0.0013
	# EPT Families	↓	0.163	23.931	< 0.0001
	% Dominant Family	↑	0.057	7.398	0.0075
	Simpson's Diversity	↓	0.060	7.852	0.0059
	FBI	↓	0.320	57.865	< 0.0001
% Meadow	% EPT	↑	0.004	0.448	0.5044
	% Gastropoda	↓	0.001	0.112	0.7388
	% Oligochaeta	↓	0.013	1.578	0.2115
	% Chironomidae	↓	0.001	0.104	0.7482
	Family Richness	↑	0.061	8.039	0.0054
	# Trichoptera Families	↑	0.016	2.026	0.1572
	# EPT Families	↑	0.043	5.592	0.0196
	% Dominant Family	↓	0.052	6.699	0.0108
	Simpson's Diversity	↑	0.042	5.383	0.0220
	FBI	↓	0.097	13.220	0.0004
% Successional	% EPT	↑	0.024	2.972	0.0872
	% Gastropoda	↓	0.018	2.264	0.1351
	% Oligochaeta	↓	0.079	10.591	0.0015
	% Chironomidae	↓	0.021	2.663	0.1053
	Family Richness	↑	0.075	9.924	0.0020
	# Trichoptera Families	↑	0.042	5.405	0.0217
	# EPT Families	↑	0.094	12.768	0.0005
	% Dominant Family	↓	0.022	2.771	0.0987
	Simpson's Diversity	↑	0.026	3.334	0.0703
	FBI	↓	0.209	32.577	< 0.0001
% Wetland	% EPT	↑	0.027	3.428	0.0665
	% Gastropoda	↓	0.005	0.628	0.4295
	% Oligochaeta	↓	0.090	12.095	0.0007
	% Chironomidae	↑	0.050	6.461	0.0126
	Family Richness	↑	0.228	36.366	< 0.0001

Environmental Variable	Index	Trend	R^2	F	p
	# Trichoptera Families	↑	0.128	18.002	< 0.0001
	# EPT Families	↑	0.202	31.101	< 0.0001
	% Dominant Family	↓	0.111	15.370	0.0001
	Simpson's Diversity	↑	0.119	16.618	< 0.0001
	FBI	↓	0.236	38.083	< 0.0001
% L1 Cover	% EPT	↓	0.001	0.094	0.7603
	% Gastropoda	↓	0.006	0.782	0.3783
	% Oligochaeta	↓	0.007	0.809	0.3702
	% Chironomidae	↓	0.019	2.349	0.1280
	Family Richness	↓	0.012	1.513	0.2211
	# Trichoptera Families	↓	0.008	1.022	0.3141
	# EPT Families	↓	0.004	0.465	0.4967
	% Dominant Family	↑	0.040	5.143	0.0251
	Simpson's Diversity	↓	0.055	7.059	0.0089
	FBI	↓	0.008	0.998	0.3197
% L2 Cover	% EPT	↑	0.057	7.465	0.0072
	% Gastropoda	↓	0.005	0.600	0.4399
	% Oligochaeta	↓	0.075	9.968	0.0020
	% Chironomidae	↓	0.060	7.827	0.0060
	Family Richness	↑	0.083	11.129	0.0011
	# Trichoptera Families	↑	0.060	7.907	0.0057
	# EPT Families	↑	0.130	18.399	< 0.0001
	% Dominant Family	↓	0.049	6.277	0.0135
	Simpson's Diversity	↑	0.042	5.415	0.0216
	FBI	↓	0.196	29.943	< 0.0001
% L3 Cover	% EPT	↑	0.037	4.678	0.0325
	% Gastropoda	↓	0.008	0.982	0.3237
	% Oligochaeta	↓	0.159	23.321	< 0.0001
	% Chironomidae	↓	0.016	1.941	0.1661
	Family Richness	↑	0.336	62.163	< 0.0001
	# Trichoptera Families	↑	0.165	24.246	< 0.0001
	# EPT Families	↑	0.270	45.533	< 0.0001
	% Dominant Family	↓	0.146	21.638	< 0.0001
	Simpson's Diversity	↑	0.177	26.490	< 0.0001
	FBI	↓	0.389	78.230	< 0.0001
% L4 Cover	% EPT	↓	0.042	5.397	0.0218
	% Gastropoda	↑	0.011	1.329	0.2512
	% Oligochaeta	↑	0.095	12.929	0.0005
	% Chironomidae	↑	0.034	4.267	0.0409

Environmental Variable	Index	Trend	R^2	F	p
	Family Richness	↓	0.170	25.210	< 0.0001
	# Trichoptera Families	↓	0.126	17.756	< 0.0001
	# EPT Families	↓	0.207	32.187	< 0.0001
	% Dominant Family	↑	0.046	5.918	0.0164
	Simpson's Diversity	↓	0.049	6.351	0.0130
	FBI	↑	0.209	32.585	< 0.0001
% L5 Cover	% EPT	↓	0.017	2.134	0.1466
	% Gastropoda	↓	0.011	1.413	0.2369
	% Oligochaeta	↑	0.140	20.052	< 0.0001
	% Chironomidae	↑	0.015	1.900	0.1706
	Family Richness	↓	0.249	40.638	< 0.0001
	# Trichoptera Families	↓	0.073	9.626	0.0024
	# EPT Families	↓	0.119	16.648	< 0.0001
	% Dominant Family	↑	0.124	17.449	< 0.0001
	Simpson's Diversity	↓	0.152	22.107	< 0.0001
	FBI	↑	0.265	44.383	< 0.0001
Catchment Area	% EPT	↑	0.058	7.533	0.0070
	% Gastropoda	↓	0.004	0.445	0.5058
	% Oligochaeta	↓	0.011	1.312	0.2543
	% Chironomidae	↓	0.003	0.361	0.5490
	Family Richness	↓	0.000	0.001	0.9736
	# Trichoptera Families	↑	0.008	1.016	0.3154
	# EPT Families	↑	0.035	4.455	0.0368
	% Dominant Family	↓	0.001	0.116	0.7342
	Simpson's Diversity	↑	0.002	0.264	0.6081
	FBI	↓	0.019	2.321	0.1302
Road Density	% EPT	↓	0.069	9.153	0.0030
	% Gastropoda	↓	0.000	0.262	0.8717
	% Oligochaeta	↑	0.224	35.415	< 0.0001
	% Chironomidae	↑	0.044	5.630	0.0192
	Family Richness	↓	0.403	82.975	< 0.0001
	# Trichoptera Families	↓	0.186	28.107	< 0.0001
	# EPT Families	↓	0.299	52.527	< 0.0001
	% Dominant Family	↑	0.141	20.216	< 0.0001
	Simpson's Diversity	↓	0.173	25.805	< 0.0001
	FBI	↑	0.409	85.361	< 0.0001
Stream Order	% EPT	↑	0.064	8.369	0.0045
	% Gastropoda	↓	0.002	0.266	0.6069
	% Oligochaeta	↓	0.061	7.951	0.0056

Environmental Variable	Index	Trend	R^2	F	p
	% Chironomidae	↑	0.035	4.516	0.0356
	Family Richness	↑	0.084	11.285	0.0010
	# Trichoptera Families	↑	0.074	9.759	0.0015
	# EPT Families	↑	0.128	18.112	< 0.0001
	% Dominant Family	↓	0.065	8.619	0.0040
	Simpson's Diversity	↑	0.080	10.743	0.0014
	FBI	↓	0.084	11.315	0.0010
Average Width	% EPT	↑	0.018	2.208	0.1399
	% Gastropoda	↓	0.006	0.752	0.3877
	% Oligochaeta	↓	0.003	0.320	0.5250
	% Chironomidae	↓	0.001	0.163	0.6875
	Family Richness	↓	0.019	2.410	0.123
	# Trichoptera Families	↑	0.000	0.015	0.9034
	# EPT Families	↑	0.002	0.188	0.6653
	% Dominant Family	↑	0.001	0.181	0.6712
	Simpson's Diversity	↓	0.001	0.097	0.7558
	FBI	↑	0.008	0.971	0.3264
Average Depth	% EPT	↓	0.041	5.294	0.0231
	% Gastropoda	↑	0.002	0.236	0.6283
	% Oligochaeta	↑	0.064	8.341	0.0046
	% Chironomidae	↑	0.013	1.601	0.2082
	Family Richness	↓	0.014	1.694	0.1956
	# Trichoptera Families	↓	0.027	3.355	0.0694
	# EPT Families	↓	0.039	4.998	0.0272
	% Dominant Family	↑	0.017	2.109	0.1490
	Simpson's Diversity	↓	0.020	2.515	0.1153
	FBI	↑	0.069	9.086	0.0031
Width/Depth Ratio	% EPT	↑	0.112	15.529	0.0001
	% Gastropoda	↓	0.009	1.163	0.283
	% Oligochaeta	↓	0.008	1.011	0.3167
	% Chironomidae	↓	0.016	1.953	0.1648
	Family Richness	↓	0.003	0.420	0.5180
	# Trichoptera Families	↑	0.031	3.995	0.0478
	# EPT Families	↑	0.053	6.858	0.0099
	% Dominant Family	↓	0.007	0.818	0.3676
	Simpson's Diversity	↑	0.018	1.026	0.314
	FBI	↓	0.009	1.142	0.2872
D16	% EPT	↑	0.001	8.290	0.0047
	% Gastropoda	↓	0.018	2.269	0.1346

Environmental Variable	Index	Trend	R^2	F	p
	% Oligochaeta	↓	0.015	1.827	0.1790
	% Chironomidae	↓	0.000	0.015	0.9018
	Family Richness	↓	0.008	0.938	0.3346
	# Trichoptera Families	↓	0.002	0.192	0.6623
	# EPT Families	↓	0.005	0.628	0.4297
	% Dominant Family	↑	0.014	1.656	0.2005
	Simpson's Diversity	↓	0.007	0.905	0.3532
	FBI	↑	0.005	0.548	0.4604
D50	% EPT	↑	0.047	5.913	0.0165
	% Gastropoda	↓	0.000	0.026	0.8726
	% Oligochaeta	↓	0.014	1.7527	0.1880
	% Chironomidae	↑	0.001	0.135	0.7142
	Family Richness	↓	0.015	1.815	0.1804
	# Trichoptera Families	↓	0.003	0.313	0.5770
	# EPT Families	↓	0.000	0.031	0.8605
	% Dominant Family	↓	0.000	0.002	0.9623
	Simpson's Diversity	↑	0.000	0.011	0.9158
	FBI	↑	0.000	0.006	0.9408
D84	% EPT	↑	0.006	0.682	0.4107
	% Gastropoda	↑	0.000	0.033	0.8557
	% Oligochaeta	↓	0.007	0.862	0.3550
	% Chironomidae	↓	0.029	0.000	0.8661
	Family Richness	↓	0.029	3.679	0.0575
	# Trichoptera Families	↓	0.013	1.563	0.2137
	# EPT Families	↓	0.011	1.396	0.2398
	% Dominant Family	↑	0.004	0.508	0.4775
	Simpson's Diversity	↓	0.004	0.458	0.4997
	FBI	↑	0.008	0.916	0.3404
% Pools	% EPT	↓	0.203	31.329	< 0.0001
	% Gastropoda	↓	0.003	0.414	0.5214
	% Oligochaeta	↑	0.111	15.300	0.0002
	% Chironomidae	↑	0.031	3.969	0.0486
	Family Richness	↓	0.021	2.692	0.1034
	# Trichoptera Families	↓	0.123	17.221	< 0.0001
	# EPT Families	↓	0.144	20.624	< 0.0001
	% Dominant Family	↑	0.026	3.280	0.0726
	Simpson's Diversity	↓	0.030	3.773	0.0544
	FBI	↑	0.131	18.486	< 0.0001
% Riffles	% EPT	↑	0.170	25.148	< 0.0001

Environmental Variable	Index	Trend	R^2	F	p
	% Gastropoda	↑	0.003	0.386	0.5357
	% Oligochaeta	↓	0.087	11.785	0.0008
	% Chironomidae	↓	0.024	3.002	0.0857
	Family Richness	↑	0.017	2.073	0.1524
	# Trichoptera Families	↑	0.088	11.932	0.0008
	# EPT Families	↑	0.114	15.858	0.0001
	% Dominant Family	↓	0.014	1.774	0.1853
	Simpson's Diversity	↑	0.018	2.266	0.1348
	FBI	↓	0.105	14.386	0.0002
% Glides	% EPT	↑	0.035	4.416	0.0376
	% Gastropoda	↑	0.001	0.128	0.7215
	% Oligochaeta	↓	0.059	7.654	0.0065
	% Chironomidae	↓	0.014	1.751	0.1882
	Family Richness	↑	0.037	4.743	0.0313
	# Trichoptera Families	↑	0.083	11.088	0.0011
	# EPT Families	↑	0.075	10.042	0.0019
	% Dominant Family	↓	0.039	5.001	0.0271
	Simpson's Diversity	↑	0.037	4.748	0.0312
	FBI	↓	0.076	10.163	0.0018

A6. CA & CCA Eigenvalues

Eigenvalues from the first three axes of Correspondence Analysis (CA) and Canonical Correspondence Analysis (CCA)

		Eigenvalues	Cumulative % of Eigenvalues	Sum of Eigenvalues
CA	Axis 1	0.27123	13.2	2.06452
	Axis 2	0.19304	22.5	
	Axis 3	0.15911	30.2	
CCA	Axis 1	0.20208	28.5	0.70916
	Axis 2	0.10579	43.4	
	Axis 3	0.07451	53.9	

A7. Average Index Values by Watershed (2001-2008)

Index	Watershed	Average	Std Dev	N
# EPT Families	Carruthers	1.19	0.93	21
	Don	1.72	0.99	154
	Duffins	4.19	2.09	140
	Etobicoke	2.26	1.46	102
	Frenchman's	0.82	0.85	22
	Highland	1.29	1.02	78
	Humber	3.42	2.04	284
	Mimico	1.18	1.00	34
	Petticoat	1.41	0.94	17
	Rouge	3.22	1.81	196
# Families	Carruthers	10.76	3.03	21
	Don	7.89	2.67	154
	Duffins	12.35	3.60	139
	Etobicoke	10.14	3.67	101
	Frenchman's	7.32	3.26	22
	Highland	6.64	2.37	78
	Humber	11.70	3.56	283
	Mimico	7.24	2.77	34
	Petticoat	8.41	2.81	17
	Rouge	12.03	3.33	196
# Trichoptera Families	Carruthers	0.52	0.51	21
	Don	0.84	0.71	154
	Duffins	1.85	1.20	139
	Etobicoke	1.05	0.88	101
	Frenchman's	0.36	0.49	22
	Highland	0.69	0.73	78
	Humber	1.43	1.06	283
	Mimico	0.59	0.70	34
	Petticoat	0.76	0.56	17
	Rouge	1.51	0.98	196
% Chironomidae	Carruthers	23.89	12.99	21
	Don	28.33	20.04	154
	Duffins	34.50	18.68	139
	Etobicoke	38.09	23.61	101
	Frenchman's	47.69	27.29	22
	Highland	45.89	25.52	78
	Humber	37.28	20.53	283
	Mimico	37.56	25.50	34

Index	Watershed	Average	Std Dev	N
	Petticoat	34.13	27.41	17
	Rouge	39.50	19.42	196
% EPT	Carruthers	4.22	7.66	21
	Don	23.10	22.39	154
	Duffins	22.77	15.37	139
	Etobicoke	10.59	11.40	101
	Frenchman's	1.98	2.85	22
	Highland	11.34	15.57	78
	Humber	22.40	18.29	283
	Mimico	11.21	16.87	34
	Petticoat	3.36	3.73	17
	Rouge	21.35	17.90	196
% Gastropoda	Carruthers	0.71	1.55	21
	Don	1.17	2.83	154
	Duffins	1.74	3.80	139
	Etobicoke	3.24	6.96	101
	Frenchman's	1.85	3.71	22
	Highland	1.22	3.66	78
	Humber	2.04	4.27	283
	Mimico	0.91	4.32	34
	Petticoat	0.76	1.35	17
	Rouge	1.90	3.90	196
% Oligochaeta	Carruthers	5.63	6.20	21
	Don	28.11	23.36	154
	Duffins	5.51	8.88	139
	Etobicoke	8.75	10.07	101
	Frenchman's	18.30	22.04	22
	Highland	25.61	23.56	78
	Humber	10.61	15.05	283
	Mimico	19.09	19.88	34
	Petticoat	2.19	2.28	17
	Rouge	6.21	8.31	196
% Plecoptera	Carruthers	0.00	0.00	21
	Don	0.00	0.00	154
	Duffins	0.45	1.82	139
	Etobicoke	0.01	0.10	101
	Frenchman's	0.00	0.00	22
	Highland	0.00	0.00	78
	Humber	0.34	1.37	283
	Mimico	0.00	0.00	34

Index	Watershed	Average	Std Dev	N
	Petticoat	0.49	1.29	17
	Rouge	0.34	1.91	196
% Dominant Family	Carruthers	38.98	11.31	21
	Don	49.61	17.48	154
	Duffins	42.41	15.34	140
	Etobicoke	51.60	19.84	102
	Frenchman's	64.08	16.43	22
	Highland	59.44	16.77	78
	Humber	46.36	16.22	284
	Mimico	55.58	16.55	34
	Petticoat	61.15	14.79	17
	Rouge	45.19	15.35	196
FBI	Carruthers	6.49	0.47	21
	Don	7.28	0.97	154
	Duffins	5.85	0.66	139
	Etobicoke	6.73	0.64	101
	Frenchman's	7.27	0.83	22
	Highland	7.18	0.90	78
	Humber	6.13	0.78	283
	Mimico	7.27	0.74	34
	Petticoat	6.55	0.61	17
	Rouge	5.98	0.54	196
Simpson's Diversity	Carruthers	0.74	0.09	21
	Don	0.63	0.17	154
	Duffins	0.72	0.13	139
	Etobicoke	0.63	0.20	101
	Frenchman's	0.50	0.18	22
	Highland	0.55	0.17	78
	Humber	0.69	0.15	283
	Mimico	0.58	0.17	34
	Petticoat	0.54	0.17	17
	Rouge	0.70	0.13	196

Appendix B – Environmental Variables

B1. GIS Derived Indices

Catchment Area – The drainage area (km^2) upstream of RWMP sites was calculated using ArcHydro 9 tools.

Land-use (% Urban, % Urbanizing, % Rural) – The percentage of land-use types (urban, urbanizing, rural) located in the upstream catchment area. The three categories were derived from the TRCA's Natural Heritage Planning Zones (NH_PlanningZones.shp). "Urban" areas are considered any part of the landscape that has been modified primarily for human use other than agriculture/forestry (includes residential, commercial, industrial land, roads, manicured areas such as cemeteries, golf courses, and parkland). Urban land cover was based on 2002 orthoimagery, urbanizing land cover was based on various regional Official Plans (2002-2004) and rural land cover was the remaining areas.

Natural Cover (% Forest, % Successional, % Wetland, % Meadow, % Beach/Bluff) – The percentage of natural cover located in each upstream catchment area. This data is based on TRCA's natural cover layer (NatCov_trca.shp) which was digitized from 2002 orthophotos. A description of the natural cover types is provided in the table below and additional information can be found in the TRCA's *Terrestrial Natural Heritage System Strategy* (TRCA 2007).

Habitat Type or Land Use	Community Types Considered
Forest	Coniferous, mixed, deciduous forest communities, b plantations, treed-swamps
Successional	Cultural woodlands and thickets
Wetland	Shallow marsh, meadow marsh, shallow aquatic ponds (where water is known to be less than 2 m deep), thicket swamps and treed-swamps where known to exist; meadow marsh (often indistinguishable from drier meadows cannot always be mapped accurately unless known to exist)
Meadow	Old field habitat or cultural meadows, natural tall-grass prairie, sand barren (sometimes meadow marsh are included in this category)
Beach/Bluff	Natural barren coastal habitats not corresponding to other habitat types, including natural beach, coastal dunes and bluffs

L-rank (% L1, % L2, % L3, % L4, % L5) – The percentage of L-rank scores for habitat patches located in each upstream catchment area. L-Rank scores are based on the quality, distribution, and quantity of natural cover (see *Terrestrial Natural Heritage System Strategy* (TRCA 2007) where L1 is the highest rank and L5 the lowest. The L-rank scores were determined using the TRCA's TNHSS scoring layer (nhscoresexisting_trca.shp). The patch evaluations were performed on the 2002 natural cover layer.

Slope – The mean slope for each catchment area calculated using the 2002 TRCA Digital Elevation Model.

Road Density – The density of roads (km/km^2) in the upstream catchment area. Road density was calculated as the number of kilometres of road per square kilometre of catchment area.

Stream Order – A general way of describing the size of a stream or river using increasing numbers as measure of the streams branching complexity. A number is assigned to a stream segments which indicates the relative importance of the segment within the drainage basin (Strahler 1957). A stream with no tributaries (headwater stream) is considered a first order stream. A segment downstream of the confluence of two first order streams is a second order stream, and so on. Stream order was based on TRCA's GIS watercourse layer.

B2. OSAP Derived Indices

The Ontario Stream Assessment Protocol (OSAP) contains a series of standardized methodologies for identifying sites, evaluating benthic macroinvertebrates, fish communities, physical habitat and water temperature in wadeable streams (Stanfield 2001).

Average Width – Determined by taking the average of the wetted widths (i.e. stream width including undercuts but excluding the width of islands) measured at each transect.

Average Depth – Determined by taking the average water depth (average of several measurements taken along a transect) measured at each transect.

Width/Depth Ratio – The average stream width divided by the average stream depth.

D16, D50, D84 – Sediment size is ranked by particle diameter; the D16, D50 and D84 diameters correspond to those particle sizes that 16, 50 and 84 percent of the sampled bed area is covered by particles smaller than the given size.

% Pools, % Riffles, % Glides – The percentage of riffles (areas of relatively fast, turbulent flow; typically occur at cross-over locations; poorly defined thalweg), pools (deepest locations of the reach; often located at the outside of meander bends) and glides (located immediately downstream of pools, deeper area without surface turbulence, uniform channel bottom.).