Regional Watershed Monitoring Program

Fish Community Summary – 2001-2009

Watershed Monitoring and Reporting Section

Ecology Division

TORONTO AND REGION Conservation
for The Living City

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1. Introduction

Many significant changes have occurred in the Toronto region since the arrival of European settlers, and these changes continue to occur at rates faster than those due to natural fluctuation. Much of the forested landscape was converted to agricultural uses in the 19th and (early) 20th century. As the land was cleared there was a shift to largely surface water contributions to the streams. Many of the Toronto region's watersheds would have historically been dominated by groundwater flow resulting in coldwater stream conditions and coldwater fish communities. As the landscape was and continues to be modified to accommodate the expanding city population, additional changes to the hydrology and water quality have affected our aquatic habitats. Different types of land cover such as urban, agriculture or forested have been shown to shape fish communities (Jackson *et al.*, 2001; Wilson and Xenopoulos, 2008) with less diversity and abundance often associated with streams in urban environments.

Aquatic ecosystems that support a diverse community of fish are considered to be healthier and more resilient to both natural and human induced stressors such as chemical spills, floods, invasive species, and climate change. Gauging the current structure of the fish community in our streams and rivers is an important step towards understanding how successful we are at protecting and managing these ecosystems. Measuring and reporting on the state of the fish community over time offers a way for agencies, regional and local municipalities, community groups, businesses and other stakeholders, to identify when land use practices and/or management strategies, techniques or actions may need to be modified such that negative trends in fish biodiversity can be reversed or prevented.

The Regional Watershed Monitoring Program (RWMP) is a science based, long-term monitoring initiative developed by the Toronto and Region Conservation Authority (TRCA). Its purpose is to collect and report on aquatic and terrestrial ecosystem data within watersheds and across the Toronto region as a whole (TRCA 2001). The program provides the data and information that informs the key planning and reporting mechanisms of the TRCA – specifically watershed report cards, watershed strategies and management plans. Since its inception in 2001, the program has enhanced the planning and coordination of monitoring activities, helped standardize protocols, and has filled several key data gaps that have been identified (TRCA 2008). It also facilitates the communication of data availability and data sharing both internally and with external agencies.

The purpose of this report is to present nine years of fish community data collected through the RWMP across TRCA's 9 watersheds (Etobicoke Creek, Mimico Creek, Humber River, Don River, Highland Creek, Rouge River, Petticoat Creek, Duffins Creek, and Carruthers Creek) in order to present a current benchmark of fish biodiversity and document any spatial and temporal changes that have occurred or are currently occurring in our fish community. One of the goals of this report is to outline the biotic and abiotic variables that influence our fish community. This is accomplished by interpreting the collected fish and habitat data based on several biological metrics and landscape variables.

This report addresses the following questions:

1. *What is the current state of fish biodiversity across the TRCA jurisdiction and within each of its nine watersheds?*
2. *Are there differences in the fish community between watersheds?*
3. *Has the fish community changed over time in each watershed and throughout the jurisdiction as a whole?*
4. *What does the fish community indicate regarding the health of our streams and rivers as indicated by the various metrics assessed?*
5. *What is the relationship between urbanization and the fish communities found within the region's watersheds?*

2. Methods

2.1 Sample Site Selection

A total of 149 sites across 9 watersheds (Etobicoke Creek, Mimico Creek, Humber River, Don River, Highland Creek, Rouge River, Petticoat Creek, Duffins Creek, and Carruthers Creek) were sampled between 2001 and 2009. These sites were sampled on a 3-year rotation such that a total of approximately 50 sites were sampled per year between June and October (Table 1). The number of sites per watershed was roughly proportional to the size of the watershed and did not change throughout sampling. Site location remained the same throughout the 2001-2009 sampling period. Figure 1 indicates the location of all RWMP fish monitoring sites.

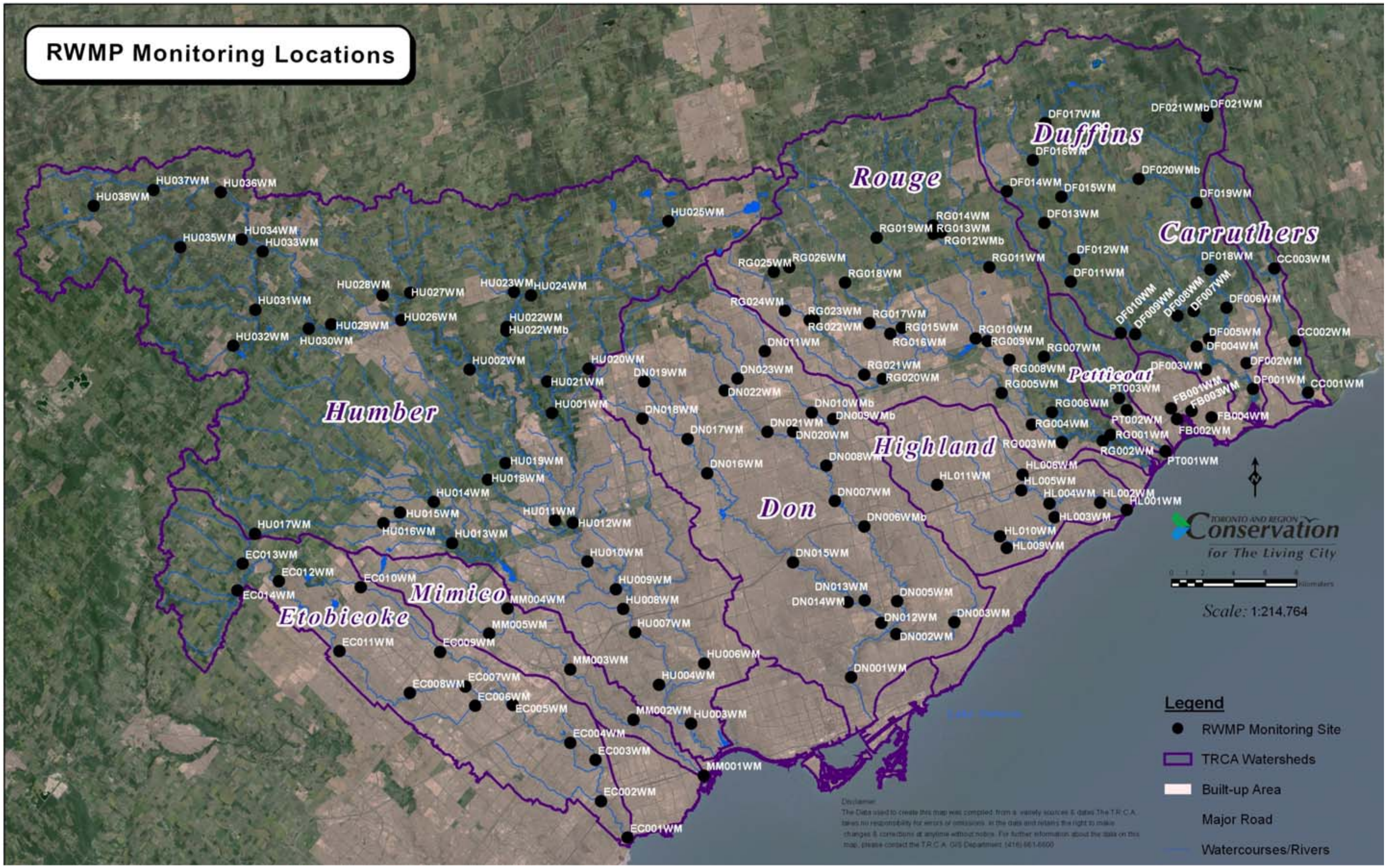

Figure 1: Map of the Toronto and Region Conservation Authority jurisdiction and RWMP sampling sites.

Table 1: Fish community and aquatic habitat sampling rotation. Number of sites sampled each year is represented by n.

2001, 2004, 2007	2002, 2005, 2008	2003, 2006, 2009
Humber River (n = 38)	Don River (n = 23)	Duffins Creek (n = 21)
Etobicoke Creek (n = 14)	Highland Creek (n = 11)	Rouge River (n = 26)
Petticoat Creek (n = 4)	Mimico Creek (n = 5)	Carruthers Creek (n = 3)

Sites were selected based on a random stratified design. Random sites were selected to insure that a sampling location was present at each subwatershed outlet where it was wadable. Sites were chosen irrespective of surrounding land use. Other sites were chosen to match historic sampling locations. Some modifications of sites were initially required in order to deal with private property and access permission.

Although fish data was collected at individual locations throughout the 9 watershed, in this report RWMP site data has been amassed to answer questions on a jurisdictional and watershed scale. An *a priori* power analysis revealed a significant increase in being able to determine a significant change when site data was rolled up by watershed or across all 9 watersheds (jurisdictional scale).

2.2 Fish Community Sampling

Monitoring surveys follow the methods outlined in the Ontario Stream Assessment Protocol (OSAP) (Stanfield 2005). Fish communities were sampled with a backpack electrofisher (Smith Root model SR-12 or LR-24) using a single pass approach. Electrofishing is a non-lethal sampling technique that uses electric currents and electric fields to immobilize fish, allowing capture. Captured fish were identified to species, weighed and measured and then released back into the water. Quality Assurance/Quality Control (QA/QC) of identified samples was carried out by certified TRCA staff and where the identification of a specimen was uncertain it was sent out for verification by a qualified fish taxonomist.

Under the OSAP protocol all sample sites were set-up following a standardized geomorphic unit which was a minimum of two crossovers or 40m in length (OSAP 2005). Electrofishing effort was undertaken at 7 to 15 seconds per square meter.

Aquatic habitat surveys, including both in-stream and bank assessments, were completed subsequent to the fish community surveys. The in-stream portion assesses the characteristics of the habitat. The bank assessment quantifies the riparian condition and the stability of the land bordering the stream. The habitat features documented at the site are not specifically addressed in this report.

2.3 Data Analysis

The collected fish community data was summarized through the use of certain biological metrics. Differences or changes in these metrics between watersheds and over time and space were also evaluated. The metrics included native species richness, native species richness ratio, the index of biotic integrity (IBI), catch per unit of effort (CPUE), and the biomass per unit of effort (BPUE),

Native Fish Species Richness and Native Fish Species Richness Ratio: Species richness is a common measure of biodiversity. It is typically measured as the number of different species in a given unit of area. The TRCA is interested in protecting, improving and restoring habitat for native or indigenous fish species. To understand how well we are doing in this regard, the number of native fish species collected at each RWMP site was compared to the number of native fish species that should be present in healthy rivers and streams in Southern Ontario based on work done by Steedman (1988). This comparison was expressed as a ratio of the observed number of native fish species to expected number of native fish species. A ratio of one indicated that all expected native species were present. A ratio of 0.5 would indicate that only 50% of the expected native species were present.

Index of Biotic Integrity: The IBI score is a multivariate measure of stream quality that uses fish fauna as a biological indicator. Nine measures, or metrics, of fish community composition, grouped into four categories (species richness, local indicator species, trophic composition and fish abundance), are used to derive the IBI score. The IBI score is used to rate the overall health of the stream (site) on a scale of 9 (poor) to 45 (very good). For more information on this metric please refer to Steedman, 1988.

Catch per Unit Effort and Biomass per Unit Effort: CPUE is a metric that is used to estimate the abundance of fish per unit of area per time needed to sample that area (CPUE = Abundance / (Area / Time)). Large values of CPUE indicate large population size since many fish are captured per unit of area and time. BPUE is a metric used to estimate the quantity of fish represented in weight (BPUE = total weight of all fish / (Area / Time)). BPUE provides an idea of the weight of the fish captured. Using both metrics gives the ability to observe trends in fish abundance along with the systems productivity. In general, a healthy population is one with a large number of individuals that have for their age and length, a specific weight.

CPUE was also assessed among three thermal guilds (coldwater, coolwater, warmwater), four origin categories (native, invasive, non-native, and stocked), eight trophic guilds (benthic herbivore, benthic insectivore, benthic invertivore, carnivore, generalist, non-parasitic filterer, parasitic filterer, and water column insectivore), and twelve fish families (*Catostomidae*

[Suckers], *Centrarchidae* [Sunfishes], *Cottidae* [Sculpins], *Cyprinidae* [Carps and Minnows], *Esocidae* [Pikes], *Gasterosteidae* [Sticklebacks], *Gobiidae* [Gobies], *Ictaluridae* [Catfishes], *Percidae* [Perches and Darters], *Petromyzontidae* [Lampreys], *Salmoninae* [Salmon and Trout sub-family], *and Umbridae* [Mudminnows]). Classification of fish species into origin categories and families was based on Mandrak and Crossman, 1992. Classification of fish into thermal habitat and trophic guilds was based on the Ontario Freshwater Fishes database (Eakins, 2002).

To avoid redundancy BPUE was not assessed amongst thermal and trophic guilds, origin categories, or families because BPUE was co-related to CPUE and both showed very similar results in terms of overall trends.

2.4 Data Analysis

All statistical analysis assumed an alpha value of 0.05 to indicate significance. Each metric was checked to meet parametric assumptions; normal distribution, homogeneity of variance, and unbiased sampling. Each metric was also checked for outliers using quartile plots. Those points that appeared to be outliers were checked for their validity. No outliers were removed.

2.4.1 Analysis of Spatial Trends

Differences between watersheds: Analysis of variance (ANOVA) or the Wilcoxon test was used in order to analyze difference between watersheds using all the data gathered throughout the three sampling periods per watershed as outlined in Table 1. The Wilcoxon test was used when the data did not meet parametric assumptions. An ANOVA analysis was used for those metrics that met parametric assumptions. The ANOVA and Wilcoxon analysis tested the hypothesis *"There is a significant change in a biological metric (CPUE, BPUE, Species Richness, or IBI) or water quality variables between watersheds."*

The CPUE and BPUE data were transformed using a $Log_e(X + 1)$ transformation to improve normality. The CPUE and BPUE data met all parametric assumptions. Native species richness and the IBI scores were both transformed using a square root (sqrt(x)) transformation. However even with this transformation the data did not meet parametric assumptions. Bar graphs were used to visually represent the differences viewed between watersheds. Graphical representation of the data (CPUE and BPUE) used actual values not the values as a result of the transformation.

Effect of Urbanization: Road density was used to approximate the influence of urbanization. The assumption was made that as urbanization of a sub-catchment increases so does the road density. Road density was calculated based on the drainage area through the use of a GIS layer last updated in 2007. To get a sense of what road densities are associated with what RWMP sites refer to Figure 3.

In order to investigate differences in CPUE between different gradients of road density, road density scores or gradients were developed through GIS analysis. Five road density gradients were used based on five equal interval classes of km of road per km^2 of land area. Road density increased with an increase in score thus a road density score of one would have a lower road density then a road density score of five. A Wilcoxon test was used to look at differences in CPUE between the five road density scores.

A regression analysis was used to investigate the effect of urbanization on native fish species richness, the IBI score, and CPUE. To investigate at what road density the greatest loss of species richness has occurred and which species were lost with every 1 km increase, road density was classified into 13 categories each separated by 1km/km^2. As categories increased, so did road density. The analysis assumes that if a species was present at a site that had a high road density score of 13, it can also potentially survive at a site with a road density score of 1. It also assumes that species present at sites with a road density score of 13 were the most tolerant species. The road density at which a species was assumed to be lost was the road density score at which the species was last present. Thus, if a fish species was present at a road density score of 6 and absent at a road density score of 7, it would be assumed that the species was lost in the transition from a road density score of 6 to 7. For this analysis only presence data was used.

To separate the affects of stream order and road density on native species richness and IBI score an analysis of covariance (ANCOVA) was performed. The ANCOVA is a general linear model that is a cross between an ANOVA, which answer the general question: "*Are there significant differences between two or more groups, for example stream order two vs. Stream order six?",* and a regression analysis, which checks if there is a significant relationship between two variables (e.g. species richness or IBI score and road density). In this report, the ANCOVA was used to answer the question: "*does the size of the stream (represented by stream order which was the categorical predictor variable) affect the relationship between road density (continuous predictor variable) and native species richness, or IBI score (both of which are the dependent variables)?"* This analysis tested three null hypotheses:

1. The regression lines are all flat, which would imply that road density is not linearly related to native species richness or the IBI score.
2. The categorical variable stream order is testing the null hypothesis that all the lines are at the same level of Y. That is, none are shifted up or down compared to the rest, which would imply that native species richness or the IBI score are not affected by stream order.
3. The regression lines have the same slope and therefore are all parallel. This would imply that the linear relationship between road density and native species richness or the IBI score is the same for each Stream Order. This is also known as the homogeneity of slope assumption.

In the situation that null hypothesis 2 and 3 are not falsified the ANCOVA takes on the form of a simple regression analysis.

Stream order was calculated based on the Strahler method (Horton 1945, Strahler 1957). Stream order was assigned to each section of stream based on a digital elevation model which was last updated in 2010. The stream order ranged from a low of 2 to a high of 6. Analysis regarding the use of this model and its implications on data interpretation such as that of CPUE and native fish species richness has been presented in TRCA 2011a and b. Due to lack of

RWMP sites present in streams corresponding to a stream order of six (5 in total HU003WM, HU007WM, HU010WM, HU012WM and DF001WM) all data from RWMP sites with a stream order of 6 was removed from both the regression and ANCOVA analysis. It was thought that data based on 5 sites would not be a true and precise representation of the response of streams with a stream order of six. In order to test this hypothesis, a separate ANCOVA was run using all the data including that of the sites found within streams of the sixth order. It was found that streams of order six showed an opposite relationship between road density and native fish species richness and road density and the IBI score compared to the other stream orders.

RWMP sites which had no fish captured in them were removed for the ANCOVA and regression analysis that used the IBI score variable. The IBI score could not be calculated for these sites as a division by zero error would occur since no fish were captured at these sites. The limits of the IBI score are from 1 to 37 (Steedman, 1988). For a list of missing sites refer to Table 2.

Table 2: RWMP sites with missing IBI scores.

Site Code	Year
DN004WM	2002, 2005, 2008
DN010WMb	2005
DN020WM	2002, 2005
HL007WM	2002, 2005, 2008
HL008WM	2002, 2005, 2008
HU004WM	2004, 2007
HU005WM	2001, 2004, 2007
HU006WM	2001
HU018WM	2001
HU020WM	2007
HU021WM	2007
HU022WM	2007
MM002WM	2005
MM003WM	2005
MM004WM	2005
PT003WM	2003, 2008
PT004WM	2008
RG011WM	2009
RG013WM	2009
RG014WM	2009
RG020WM	2009
RG025WM	2009

2.4.2 Analysis of Temporal Trends

When data meets parametric assumptions, questions regarding trends are usually analyzed using a regression analysis however, this is only possible when both the x and y variables are continuous. These data sets consisted of the x variable being categorical (sampling period) or ordinal, therefore it was impossible to do a common regression of the dependent variable over time and have confidence in the resulting *p* value. Instead the sampling period was treated as an ordinal variable and a Wilcoxon test was used while forcing the sampling periods to chronological order. Temporal trends were also visually inspected by comparing the mean of each metric between sampling periods through the use of a bar graph. All trends were reported on even if they were statistically invalid. Statistically valid trends were important to note as they may become statistically significant as more data becomes available in the future sampling periods. Overlapping error bars in the bar graphs indicated insignificant differences between the sampling periods.

3. Results and Discussion

3.1 Jurisdictional Species Composition

From 2001-2009 a total of 53 fish species were captured at the 149 RWMP sampling sites throughout TRCA's jurisdiction. These species represented **12 families**; (*Catostomidae* (Suckers), *Centrarchidae* (Sunfishes), *Cottidae* (Sculpins), *Cyprinidae* (Carps and Minnows), *Esocidae* (Pikes), *Gasterosteidae* (Sticklebacks), *Gobiidae* (Gobies), *Ictaluridae* (Catfishes), *Percidae* (Perches and Darters), *Petromyzontidae* (Lampreys), *Salmoninae* (Salmon and Trout sub-family), and *Umbridae* (Mudminnows), **8 trophic guilds** (benthic herbivore, benthic insectivore, benthic invertivore, carnivore, generalist, non-parasitic filterer, parasitic filterer, and water column insectivore), **3 thermal habitat guilds** (coldwater, coolwater, and warmwater), and **4 different origin categories** (native, non-native, invasive, and stocked).

The majority of the fish captured were coolwater, native species that were either generalists or benthic insectivores belonging to the family *Cyprinidae* (Carps and Minnows), *Percidae* (Perches), or *Catostomidae* (Suckers) (Table 3 and Figure 8 to Figure 10)

Of the 53 fish species, 46 were considered native, 4 were considered invasive (Common Carp, Goldfish, Round Goby, and Sea Lamprey), 1 was considered non-native but not invasive (Central Stoneroller), and 2 were considered stocked (Rainbow Trout and Brown Trout) (Table 3). A table showing the number of individuals captured of each species by sample year and watershed can be found in Appendix A1.

Table 3 - Species name, common name, thermal guild, trophic group and abundance for all species captured from 2001-2009.

Origin	Thermal Guild	Species Common Name	Species Latin Name	Trophic Guild	Abundance Rank (total)
Native	Coldwater	Atlantic Salmon	*Salmo salar*	Carnivore	20 (254)
		Brook Trout	*Salvelinus fontinalis*	Carnivore	19 (275)
		American Brook Lamprey	*Lampetra appendix*	Nonparasitic filterer	17 (327)
		Mottled Sculpin	*Cottus bairdi*	Benthic insectivore	8 (1782)
	Coolwater	Lake Chub	*Couesius plumbeus*	Generalist	48 (1)
		Northern Pike	*Esox lucius*	Carnivore	48 (1)
		Blacknose Shiner	*Notropis heterolepis*	Benthic insectivore	47 (2)
		Brassy Minnow	*Hybognathus hankinsoni*	Benthic herbivore	45 (5)
		Pearl Dace	*Margariscus margarita*	Generalist	44 (6)
		Black Crappie	*Pomoxis nigromaculatus*	Carnivore	44 (6)
		Emerald Shiner	*Notropis atherinoides*	Water column insectivore	42 (8)
		Central Mudminnow	*Umbra limi*	Generalist	38 (14)
		Yellow Perch	*Perca flavescens*	Carnivore	37 (17)
		Blackside Darter	*Percina maculata*	Benthic insectivore	36 (25)
		Hornyhead Chub	*Nocomis biguttatus*	Generalist	29 (71)
		Spottail Shiner	*Notropis hudsonius*	Water column insectivore	27 (119)
		Northern Redbelly Dace	*Phoxinus eos*	Generalist	28 (104)
		Redside Dace	*Clinostomus elongatus*	Water column insectivore	23 (209)
		Golden Shiner	*Notemigonus crysoleucas*	Generalist	21 (240)
		River Chub	*Nocomis micropogon*	Generalist	18 (300)
		Rock Bass	*Ambloplites rupestris*	Carnivore	16 (387)
		Brook Stickleback	*Culaea inconstans*	Water column insectivore	12 (1198)
		Fantail Darter	*Etheostoma flabellare*	Benthic insectivore	11 (1201)
		Common Shiner	*Luxilus cornutus*	Generalist	7 (2700)
		Rainbow Darter	*Etheostoma caeruleum*	Benthic insectivore	6 (3392)
		Johnny Darter	*Etheostoma nigrum*	Benthic insectivore	5 (4634)
		White Sucker	*Catostomus commersoni*	Generalist	4 (4753)
		Creek Chub	*Semotilus atromaculatus*	Generalist	3 (7418)
		Longnose Dace	*Rhinichthys cataractae*	Benthic insectivore	2 (13,909)
		Blacknose Dace	*Rhinichthys atratulus*	Generalist	1 (14,113)
	Warmwater	Bluegill	*Lepomis macrochirus*	Generalist	46 (3)
		Mimic Shiner	*Notropis volucellus*	Generalist	48 (1)
		Logperch	*Percina caprodes*	Benthic insectivore	41 (9)
		Rosyface Shiner	*Notropis rubellus*	Water column insectivore	40 (10)
		Northern Hog Sucker	*Hypentelium nigricans*	Generalist	22 (222)
		Pumpkinseed	*Lepomis gibbosus*	Generalist	15 (393)
		Spotfin Shiner	*Cyprinella spiloptera*	Water column insectivore	35 (32)
		Sand Shiner	*Notropis stramineus*	Generalist	34 (49)
		Green Sunfish	*Lepomis cyanellus*	Generalist	32 (55)
		Brown Bullhead	*Ameiurus nebulosus*	Generalist	32 (55)
		Smallmouth Bass	*Micropterus dolomieu*	Carnivore	31 (58)
		Largemouth Bass	*Micropterus salmoides*	Carnivore	30 (61)
		Stonecat	*Noturus flavus*	Benthic insectivore	25 (197)
		Fathead Minnow	*Pimephales promelas*	Generalist	10 (1475)
		Bluntnose Minnow	*Pimephales notatus*	Generalist	9 (1586)
Non-native	Coolwater	Central Stoneroller	*Campostoma anomalum*	Benthic herbivore	13 (716)
Stocked	Coldwater	Brown Trout	*Salmo trutta*	Carnivore	24 (199)
		Rainbow Trout	*Oncorhynchus mykiss*	Carnivore	14 (586)
Invasive	Coolwater	Threespine Stickleback	*Gasterosteus aculeatus*	Water column insectivore	43 (7)
		Sea Lamprey	*Petromyzon marinus*	Parasitic filterer	39 (11)
		Round goby	*Neogobius melanostomus*	Benthic invertivore	26 (164)
	Warmwater	Common Carp	*Cyprinus carpio*	Generalist	36 (25)
		Goldfish	*Carassius auratus*	Generalist	33 (50)

3.2 Species Abundance

The 10 most abundant species (in order of their abundance) across the TRCA jurisdiction were the Blacknose and Longnose Dace, Creek Chub, White Sucker, Johnny Darter, Rainbow Darter, Common Shiner, Mottled Sculpin, and the Bluntnose and Fathead Minnow (Table 3). However, differences in the abundance of species occur when broken down by watershed and by sampling period (Appendix A1).

Of particular interest was the Mottled Sculpin, which was the only coldwater species found in the top 10 most abundant species. Mottled Sculpin prefer water temperatures below 17°C and reproduce in water temperatures of 5-16°C during April and May (Bailey 1952; Savage 1963). They are often used as a surrogate for trout species when assessing habitat suitability since they generally require similar water temperatures. They are also a lake inhabiting species and can be found in the lower reaches of rivers in the transitional habitats between lake and river. The CPUE of Mottled Sculpin was largest in the Humber River watershed, however they were also captured in the Don River, Rouge River, and Duffins Creek watersheds.

3.3 Native Fish Species Richness

The highest native fish biodiversity (38 native fish species) was found across the sites in the Humber River watershed. The Rouge River and Duffins Creek watersheds also had high native fish biodiversity, with a total of 29 and 31 native fish species respectively. Native fish biodiversity was the lowest across sites in the Petticoat Creek watershed with a total of nine native fish species (Figure 2).

Fish biodiversity was found to be high at RWMP sites that captured the presence of lake-based species near the mouth of some of the rivers. This highlights the important link between the watershed and Lake Ontario ecosystems. Where barriers (dams, weirs, culverts, etc.) were present downstream of the lowest RWMP station (e.g. Rouge River, Mimico Creek, Etobicoke Creek and Humber River), fish biodiversity was low as the connection to the lake is interrupted and the barriers restrict fish movement and migration (Figure 4).

Invasive species were captured at some sites in all watersheds with the exception of the Carruthers Creek. Part of the reason invasive species are considered invasive is because they cause a decrease in native fish biodiversity through their population growth and range expansion which often results in the extirpation of other fish species. Species like the Common Carp (*Cyprinus carpio*) are ecosystem engineers and their presence often results in a change in aquatic habitat that benefits them but is detrimental to other species. The Round Goby has been present in Lake Ontario since probably the early 1990's. Its first occurrence was in Lake St. Clair during1990 and by 1997 it had invaded all the great lakes. Its presence has negatively impacted the lake's native fish community (Charlebois *et al*. 1997). However, only recently (during the 2007-2009) has the TRCA's RWMP captured the species in our rivers and streams and only at sites relatively close to the lake. Continued monitoring is necessary in order to assess how our native fish community responds to the Round Goby's expansion into our streams and rivers.

The Central Stoneroller is part of the *Cyprinidae* family and is considered to be native to the southern part of Lake Ontario (United States). It has expanded its range to Northern parts of Lake Ontario and is the only non-native fish species captured through the RWMP in four out of the nine watersheds (Etobicoke Creek, Humber River, Rouge River, and Petticoat Creek) monitored. Although non-native, the Central Stoneroller has not produced any obvious negative effects on native resident species. Its classification as being non-native is the only discrepancy with the Mandrak and Crossman, 1992 classification. Mandrak and Crossman classify this fish as being native but introduced and successful at establishing itself via natural dispersal. The Ontario Freshwater Life History fishes database classifies this fish as being native/introduced.

Brown Trout and Rainbow Trout are stocked across the TRCA's jurisdiction by various organizations. Currently, they have been captured at sites within most watersheds. Exceptions include the Etobicoke Creek and Mimico Creeks, and only a single juvenile fish was captured in the Highland Creek watershed. These fish have both become naturalized to our waters and now add to the biodiversity of our aquatic ecosystem and help promote and support recreational angling. Beginning in 2006, the Atlantic Salmon has been stocked in select watersheds (Duffins Creek and Humber River) in an effort to help in the recovery of the species and to re-introduce the Atlantic Salmon back into some of its native habitat within the TRCA's jurisdiction. The Atlantic Salmon previously occupied a natural habitat range that included all of our streams and rivers on the north shore of Lake Ontario thus, although stocked in some watersheds it is still considered a native species for this analysis.

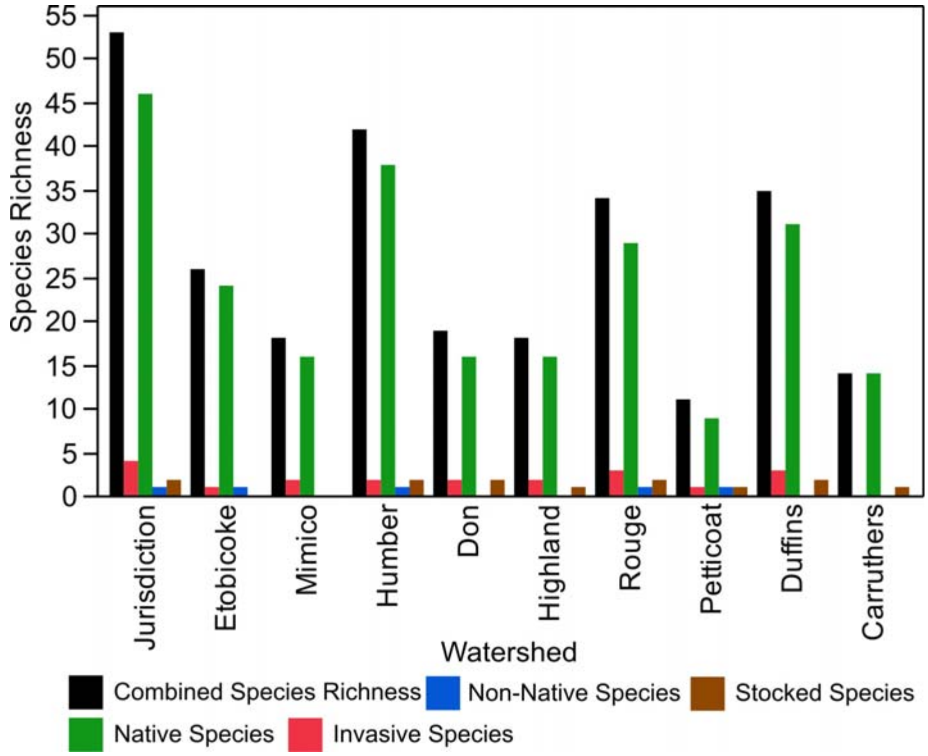

Figure 2: Total species richness and richness by origin category per watershed and for the entire TRCA jurisdiction 2001 to 2009.

3.4 Native Fish Species Richness Ratio

Overall, in the TRCA jurisdiction (data for all sites taken together) had a mean observed to expected native fish species richness ratio of 0.59 (Figure 3). Therefore, in the last nine years the RWMP captured and identified only 59% of the fish species we expect TRCA's streams and rivers can support. This can be interpreted as meaning that our jurisdiction as a whole is supporting 59% of the native fish species we expect it could support if conditions were ideal. The same type of reasoning can be applied to individual watersheds. Ratios between watersheds varied as shown in Figure 3.

However, one should also note that the RWMP was not originally designed for the purpose of acquiring a comprehensive species inventory as it only occurs during June and September, and does not specifically target all the different habitat types or seasonally occurring migratory species that can be present in a stream. Also, the sampling locations are not geographically spaced for the purpose of acquiring a comprehensive fish species inventory. Also, the less than 50% ratios in the upper Humber River watershed, and the one site that received a less than 50% ratio in the upper Duffins Creek watershed were not indicative of poor environmental conditions but were rather a function of the ratio calculation. These 5 RWMP sites have a low expected native species richness (five species or less) due to their comparatively low drainage area, hence the impact on the ratio of not finding one species is much greater at these sites compared to those who's expected native species richness is greater, such as, 10 native species or more. This is one of the disadvantageous of any ratio calculation because the magnitude of change is dependent on the denominator and the ratio changes more drastically as the denominator decreases.

The Wilcoxon test revealed a significant difference in the observed to expected native fish species richness ratio between the watershed. Among the watersheds, the Rouge River had the highest ratio (0.80) followed by Duffins Creek (0.68), Humber River (0.65) and Petticoat Creek (0.60). Etobicoke Creek and Carruthers Creek had mean ratios of 0.50 and 0.53 respectively. The Mimico Creek, Don River and Highland Creek watersheds all had ratios below 0.40. The Mimico Creek watershed had the lowest observed to expected native fish species richness ratio (0.26) (Figure 3). Out of all 9 watersheds, the Mimico Creek, Etobicoke Creek, Highland Creek, and Don River are the most urbanized.

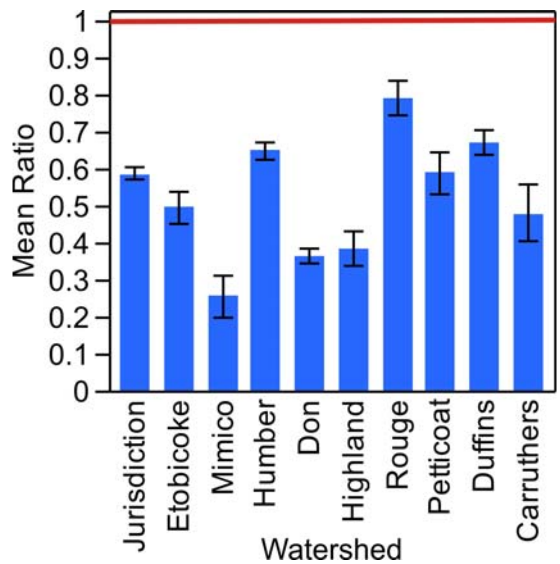

Figure 3: Mean observed:expected native species richness ratio by watershed, and entire TRCA jurisdiction. Red line indicates desired ratio or the ratio one should observe if all habitat conditions were ideal. Error bars represent ±95% confidence intervals.

Despite none of the watersheds meeting the expected native fish species ratio of one, the vast majority (86%) of the fish species captured across all the sites within the TRCA jurisdiction between all sampling periods were native species. Native species made up no less than 95% of the total catch in any sampling period across all 149 sites and no less than 90% of the total catch when the data was divided by watershed. Invasive and non-native fish species made up approximately 1% of the total number of fish captured across all the TRCA sites, and in any given sampling period in any given watershed, invasive species and non-native species made up less than a maximum of 10% of the total catch. The mean CPUE of native fish species was also much greater compared to that of non-native and invasive species whether combining the data across all the sites or dividing it by watershed (Figure 17). For specific p values associated with native fish species richness or the native fish species richness ratio please refer to Appendix A4.

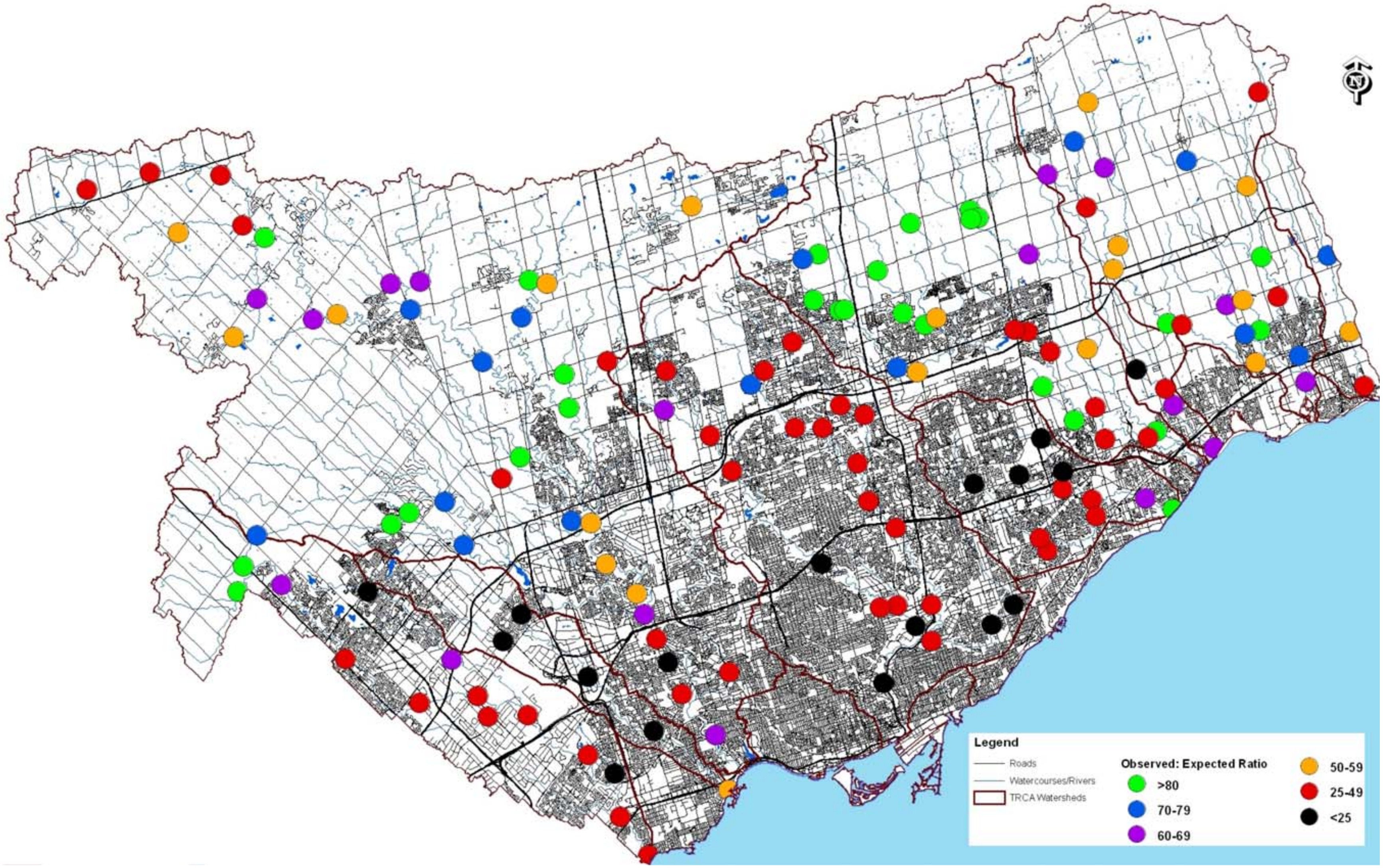

Figure 4: Observed vs. Expected Native fish species richness ratio. Dots represent RWMP Sampling sites. The four RWMP sites (Red dots) present in the upper Humber River watershed and the one RWMP site (red dot) present in the upper Duffins Creek watershed are not representative of poor quality conditions. A full explanation is present in the text above in this section. (Excluding Frenchman's Bay).

3.5 Index of Biotic Integrity

The jurisdictional mean IBI score was 23.6 which corresponds to an overall rating of fair (Figure 5 and Appendix A2 Table A2-1). The mean IBI score of the Etobicoke Creek, Mimico Creek, Don River, and Highland Creek watersheds was less than that of the jurisdictional mean (Figure 5A). The Mimico Creek and Don River watersheds had IBI scores in the range of poor while the Etobicoke Creek and Petticoat Creek watersheds had fair scores on the edge of poor. Both the Etobicoke Creek and the Petticoat Creek watershed had an IBI value that was on the border between poor or fair. The largest IBI values occurred in the Humber River, Duffins Creek, Rouge River, and Carruthers Creek watersheds. These four watersheds had mean IBI score values that were above the jurisdictional mean and in the fair range (Figure 5A). Although none of the watersheds received mean IBI scores in the good or very good range, there are individual sites in each watershed that are in the good range (Figure 5B).

The percentage of sites per IBI stream quality category (very good, good, fair, and poor) varied per watershed as shown in Figure 5B and Appendix A2 Table A2-2. Watersheds that received a mean IBI score in the category of poor (Etobicoke Creek, Mimico Creek, Don River, and Highland Creek) had few sites receiving IBI scores that are in the range of good (28-37) (Figure 5B). The Don River and Highland Creek watersheds had the lowest percentage of sites with IBI score values within the good range. The Humber River watershed, followed by the Rouge River and Duffins Creek had more than 25% of their sites receiving IBI score values in the good range and less than 18% in the poor range (Figure 5B). These watersheds also had the 3 highest mean IBI score values (Figure 5A). There are no watersheds with sites that have IBI values within the very good range.

The IBI incorporates native fish species richness as part of its mathematical function, hence watersheds such as the Humber River, Rouge River, and Duffins Creek that had high IBI scores also had the largest values in native fish species richness.

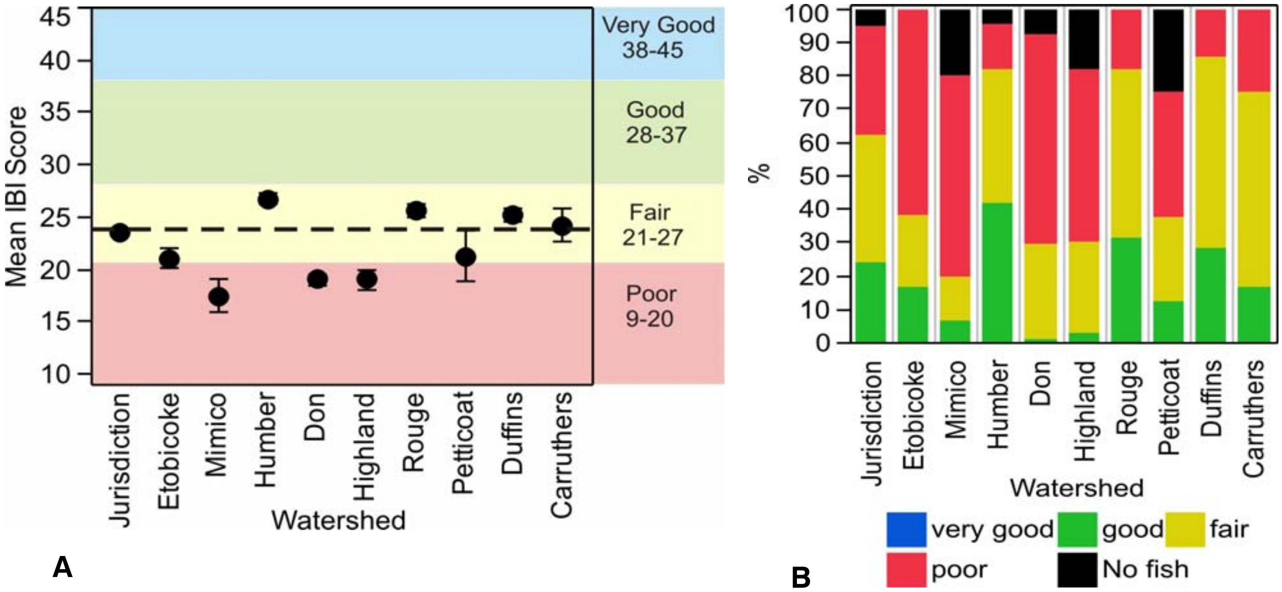

Figure 5: IBI score charts: **A)** Mean IBI score per watershed and for the entire jurisdiction. Mean was calculated based on combining all the data collected during 2001-2009. Error bars represent standard error. Dashed lines represent the jurisdictional mean. **B)** Percentage of sites in each watershed per IBI stream quality. No fish indicates no fish were captured, thus no IBI score could be calculated.

3.6 Catch per Unit Effort and Biomass per unit Effort

The jurisdictional mean CPUE was 23.57. The CPUE ranged from a low of 0.13 obtained in the Don River watershed and a high of 253.15 obtained from the Humber River watershed (Appendix A3 Table A3-1). The mean CPUE was greatest for sites within the Petticoat Creek, Highland Creek, Humber River and Etobicoke Creek watersheds. However, these values were not significantly different compared to the overall jurisdictional mean or the Rouge River or Duffins Creek watersheds as indicated in the error bars present in
Figure 6 B.

The Petticoat Creek watershed showed an unusually large mean CPUE and large level of variance. This large CPUE in Petticoat Creek was due to the unusually large number of Blacknose Dace captured during 2002 sampling. This large CPUE was not repeated in either the 2005 or 2008 sampling hence the large standard error. By excluding the large CPUE of Blacknose Dace in 2002, the mean CPUE in Petticoat Creek is reduced by approximately half. Combining all years of sampling for sites within the Mimico Creek, Don River and Carruthers Creek watersheds resulted in significantly lower values of CPUE compared to the overall jurisdictional mean and all the other watersheds with the exception of Petticoat Creek (overlapping standard error bars indicate lack of significant difference) (Figure 6 A and B). These differences among watersheds were also manifested when assessing the CPUE by thermal guilds, origin categories, trophic guilds, and fish families.

The largest range in variation among sites within a watershed, in terms of CPUE, occurred between sites within the Humber River watershed and between sites within the Petticoat Creek watershed. The least variance occurred among sites within the Mimico Creek watershed and between sites within the Carruthers Creek watershed (Appendix A3). This is indicative of the variation in habitat and water quality conditions that occur throughout these watersheds. Watersheds such as the Humber River span a large geographic area and thus have sites that are present in both ideal and disturbed or degraded habitats. Thus, some sites in the Humber River may have a large number of fish while others may have very few. The large level of variance may also speak to the lack of connectivity between the sites within the watershed and the fluctuating level of disturbance experienced by different regions of the watershed. Structures such as dams or weirs can prevent fish from occupying even the most ideal habitats, hence decreasing their abundance at sites near these barriers to movement and/or migration. Sites in urbanized areas or downstream of urbanized areas are more prone to frequent and fluctuating levels of disturbance, including changes in water quality, water level, water temperature and flow regime, which in turn influence where fish choose to aggregate within the stream and increase the source of variation amongst sampling locations and periods. Such is the case for the RWMP sites found within the Petticoat Creek watershed which experience changes in flow and water volume rendering some sites dry or with too little water to support fish thus affecting the CPUE and BPUE at the site. Watersheds that show low variation are indicative of sites that span similar habitat or have similar levels of quality throughout, thus the sites have similar numbers of fish present.

Combining all years of sampling the mean BPUE was greatest for sites within the Humber River and Rouge River watersheds (
Figure 6 A). Sites within the Don River or Carruthers Creek watersheds resulted in significantly lower values of BPUE compared to the overall jurisdiction mean. The largest variation in BPUE amongst sites within a watershed occurred between sites within the Mimico Creek watershed and between sites within the Rouge River watershed. The least variation occurred between sites within the Petticoat Creek watershed and those sites found in the Carruthers Creek watershed (Appendix A3 Table A3-1).

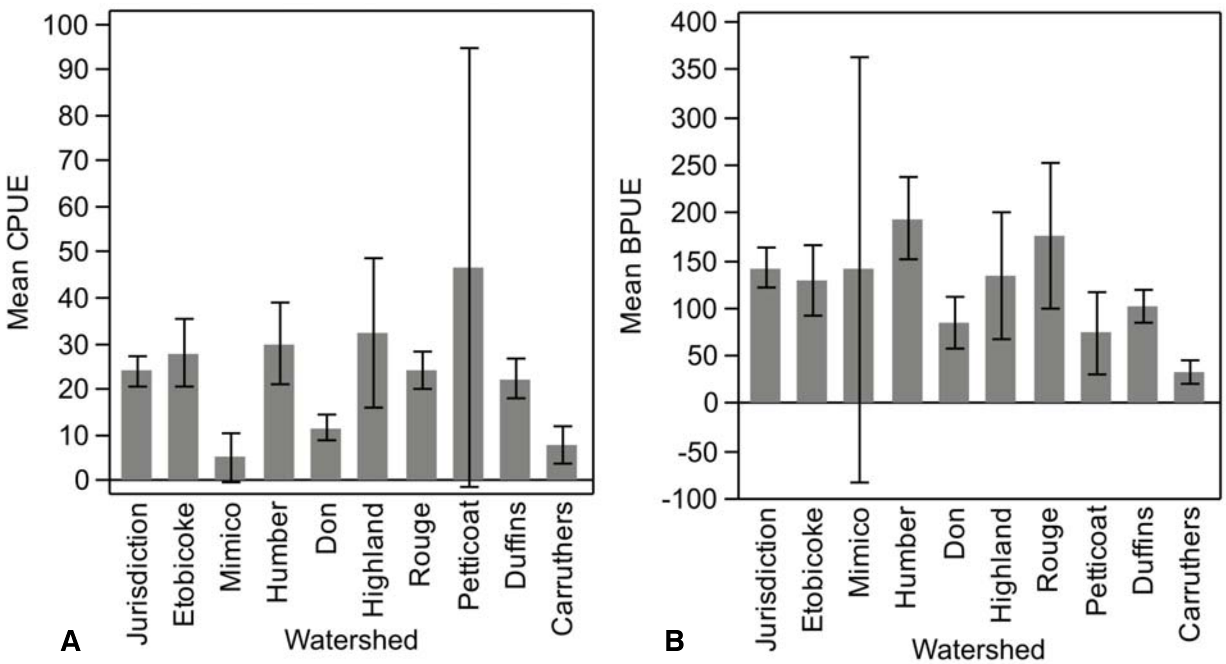

Figure 6: A) Mean BPUE **B)** Mean CPUE per watershed. Error bars represent standard error. Jurisdiction represents the mean of all sites combined.

3.7 CPUE and Thermal Regime

The majority of fish captured across our jurisdiction were coolwater species that prefer water temperatures ranging from 18°C to 24°C (Figure 7). As a result the mean jurisdictional CPUE of coolwater fish (20.59) was significantly greater than that of either warmwater (temperature preference > 25°C) or coldwater (temperature preference < 18°C) fish (CPUE: Warmwater 1.5, Coldwater 1.11). When examining the data by watershed it was found that higher mean CPUEs of coldwater fish were found in the Humber River (2.28), Rouge River (0.76), and Duffins Creek (2.07) watersheds. This was expected given the origins of these watersheds in the Oak Ridges Moraine and abundant headwater tributaries. The greatest mean CPUE of warmwater fish was in the Petticoat Creek. The Etobicoke Creek (2.83) and Carruthers Creek (2.62) watersheds also had a high CPUE for warmwater species (Figure 7). For a full list of species by thermal regime please refer to (Table 3). For specific descriptive statistics e.g. mean, minimum, maximum, standard deviation and variance please refer to Appendix A3 (Table A3-2).

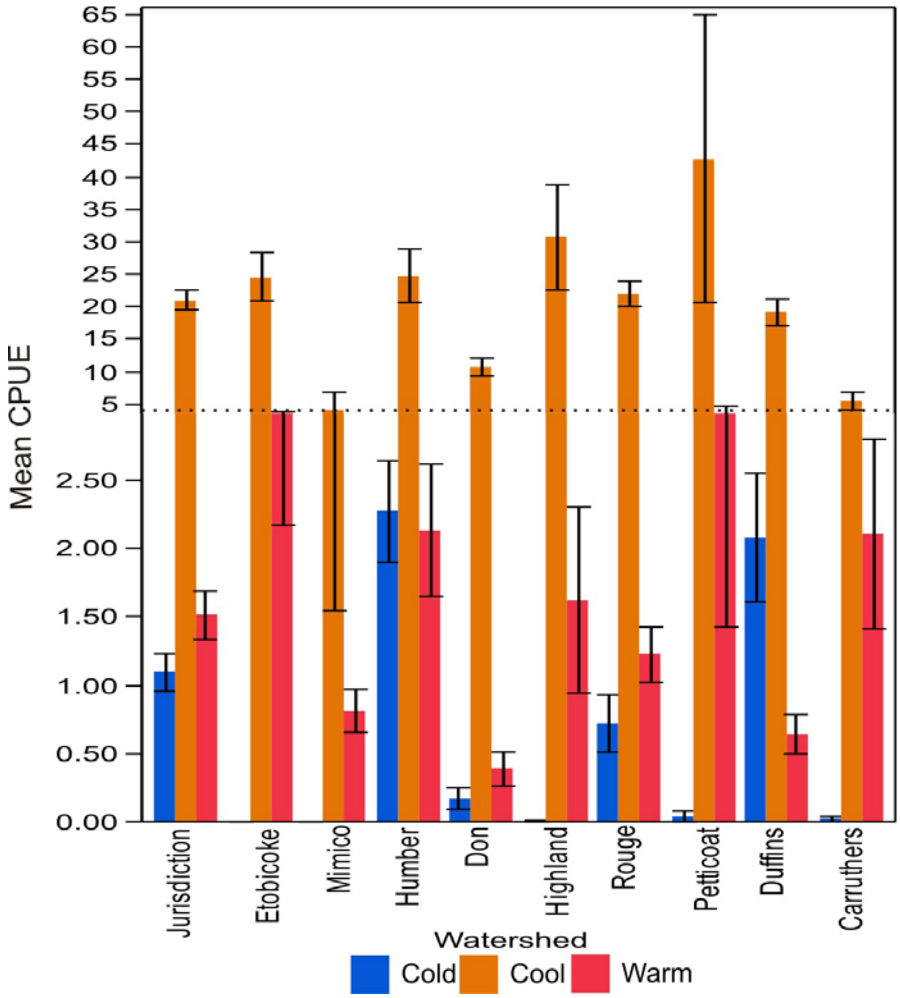

Figure 7: Mean CPUE by thermal guild per watershed for all years of sampling (2001-2009). Error bars represent standard error. Jurisdiction represents the mean of all sites combined. - - - Notes scale change.

3.8 CPUE and Fish Species Origin

Approximately 95% of the total CPUE was attributed to the capture of native fish species, both on a watershed basis and across the jurisdiction. The mean CPUE of native fish species (Jurisdictional CPUE 22.5) was significantly greater compared to that of either invasive (Jurisdictional CPUE 0.11), non-native (Jurisdictional CPUE 0.31), or stocked (Jurisdictional CPUE 0.27) fish species (Figure 8). The mean CPUE of non-native fish was strictly a function of the abundance of the Central Stoneroller which was the only fish species considered non-native within the TRCA jurisdiction. The Humber River, Rouge River, and Duffins Creek watersheds are the only watersheds that had sites which contained Rainbow and Brown Trout. These were the only two stocked fish species that the TRCA captured through its RWMP monitoring program during 2001-2009 sampling. The CPUE of invasive species was a function of the abundance of the Common Carp, Round Goby, Goldfish, and Sea Lamprey. During nine years of sampling the Carruthers Creek watershed was the only watershed that had no invasive species captured within its sites. Descriptive statistics e.g. mean, minimum, maximum, standard deviation and variance for species origin are presented in Appendix A3 (Table A3-3).

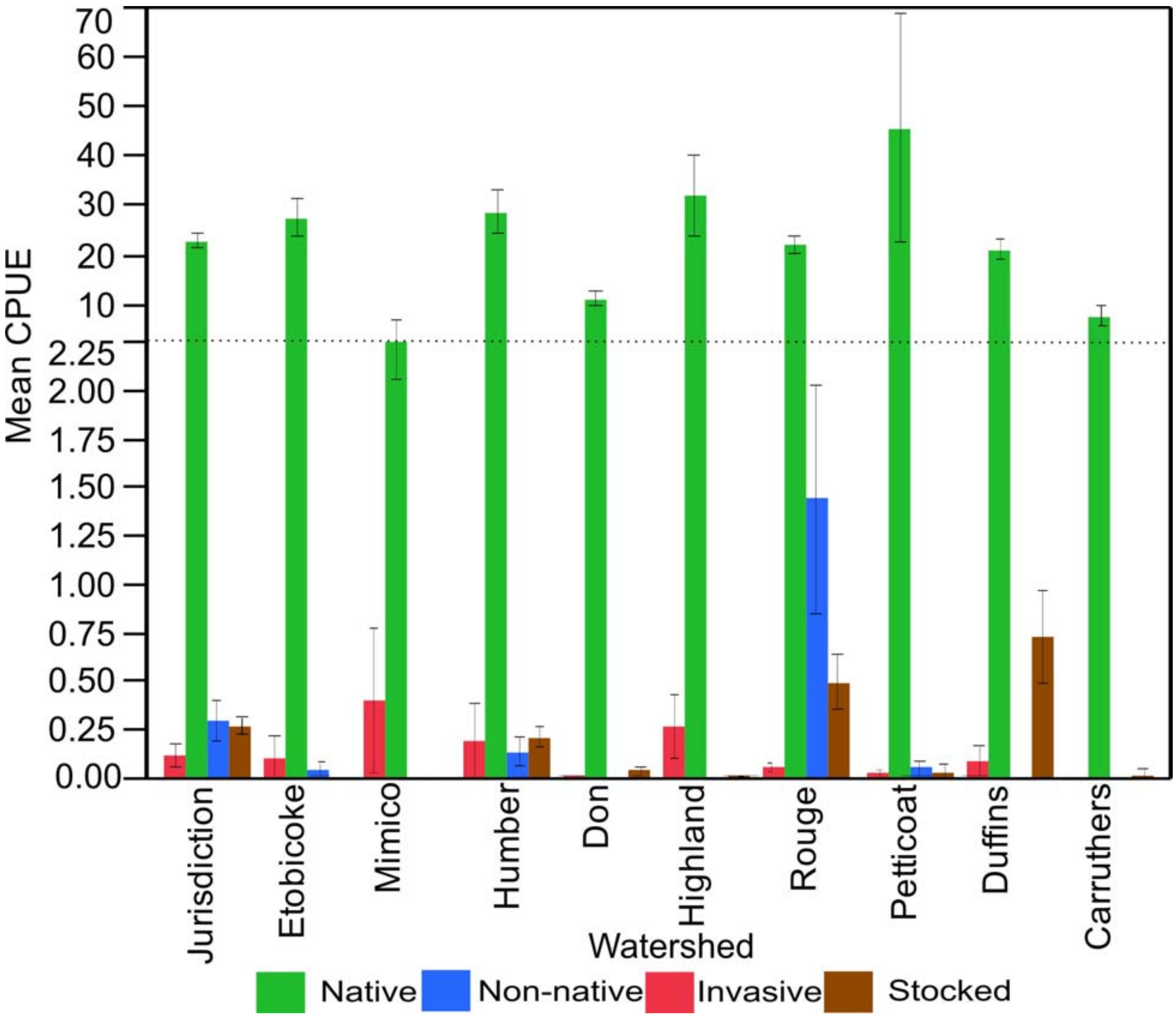

Figure 8: Mean CPUE by origin category per watershed for all years of sampling (2001-2009). Error bars represent standard error. Jurisdiction represents the mean of all sites combined. - - - Notes scale change.

3.9 CPUE and Trophic Guild

The mean CPUE of generalists (Jurisdictional CPUE 11.58) and benthic insectivores (Jurisdictional CPUE 10.04), both by watershed or throughout the jurisdiction, was significantly greater than that of any of the other trophic guilds (Figure 9). Overall there was no significant difference in the mean CPUE of generalists and benthic insectivores within the same watershed with the exception of Highland Creek and Petticoat Creek (Figure 9). The large mean CPUE of generalists in Petticoat Creek was a result of the unusually large number of Blacknose Dace captured during 2002 sampling. The large mean CPUE of generalists in Highland Creek was also due to the large number of Blacknose Dace captured during all three years of sampling. For a list of species subdivided by trophic guild please refer to Table 3. Descriptive statistics e.g. mean, minimum, maximum, standard deviation and variance for trophic guilds are presented in Appendix A3 (Table A3-4).

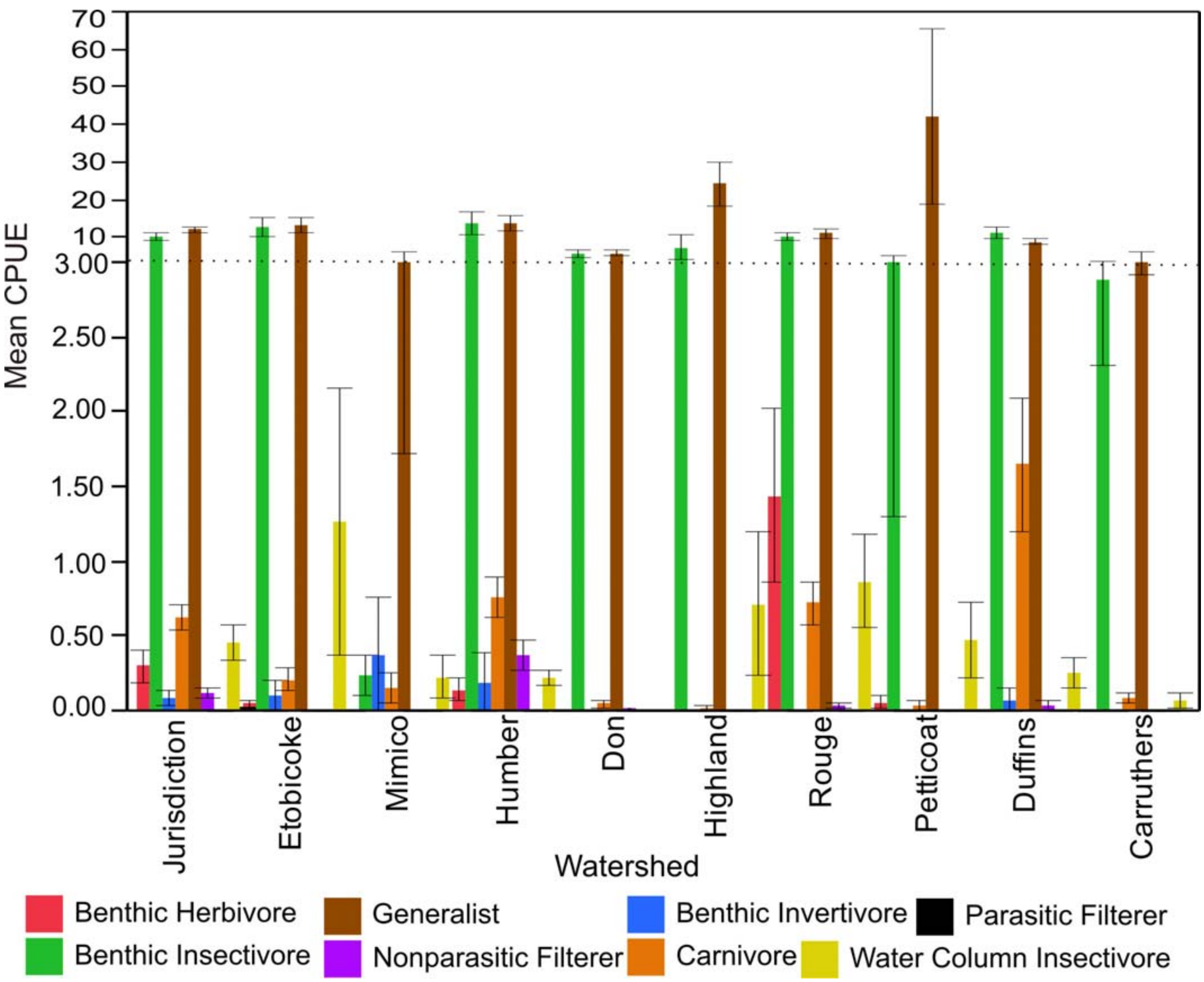

Figure 9: Mean CPUE divided by trophic guild per watershed across all years of sampling (2001-2009).Error bars represent standard error. Jurisdiction represents the mean of all sites combined.
- - - Notes scale change.

3.10 CPUE and Fish Families

Significant differences were seen among the fish families found across the jurisdiction as a whole and between watersheds (Figure 10). With the exception of Carruthers Creek the mean

CPUE of the *Cyprinidae* family (Carps and minnows) (Jurisdictional CPUE 16.29) was significantly greater than any other family groups. The Carruthers Creek watershed was comprised of both *Cyprinidae* and *Percidae* (Perch and Darters). Throughout the jurisdiction, the mean CPUE of Perches (3.56) was the second largest CPUE out of all the families. The mean CPUE of fish belonging to the *Catostomidae* family (Suckers) was third largest across the jurisdiction (1.66) and within the Don River (1.47), Highland Creek (2.73), and Rouge River (1.9) watersheds. The *Catastomidae* CPUE was largely attributed to the large abundance of the White Sucker. The Northern Hog Sucker was the only other fish species in the *Catastomidae* family that was captured through the 2001-2009 sampling. Overall, fish belonging to the *Catostomidae* (Suckers), *Centrarchidae* (Sunfishes), *Cottidae* (Sculpins), *Esocidae* (Pikes), *Gasterosteidae* (Sticklebacks), *Gobiidae* (Gobies), *Ictaluridae* (Catfishes), *Petromyzontidae* (Lampreys), *Salmoninae* (Salmon and Trout), *and Umbridae* (Mudminnows) families had similar values of CPUE however, slight differences in the mean CPUE did occur between watersheds.

Salmoninae (Salmon and Trout) had a significantly greater mean CPUE (1.56) in the Duffins Creek watershed compared to other watersheds. The mean CPUE of the Sunfish family (0.9) was significantly greater in sites within the Carruthers Creek watershed. The mean CPUE of Sculpins (1.52) was significantly greater in sites within the Humber River watershed. The *Gobiidae* family (0.38) was significantly greater in the Mimico Creek watershed. Fish belonging to the Stickleback family had significantly greater mean CPUE values in Etobicoke Creek (1.24), Highland Creek (0.74), and Rouge River (0.76) watersheds. The mean CPUE of the Pike and Mudminnow families was significantly less than that of any other fish family (Figure 10). This was expected as the species in these families have habitat requirements more often found in lentic systems as opposed to lotic systems. For a list of species by family group please refer to Table 3. Descriptive statistics e.g. mean, minimum, maximum, standard deviation and variance for fish families are presented in Appendix A3 (Table A3-4).

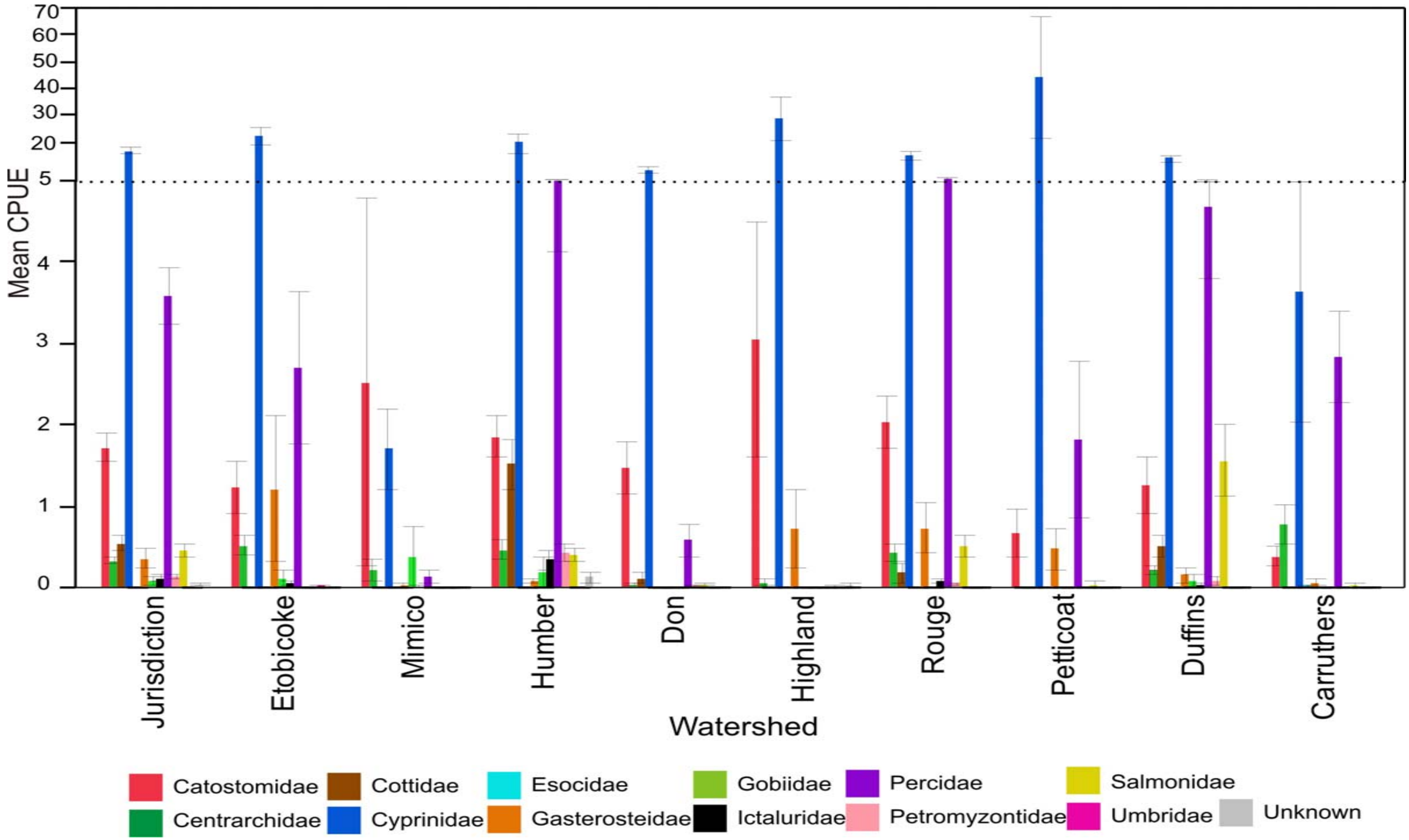

Figure 10: Mean CPUE by family guild per watershed for all years of sampling (2001-2009). Error bars represent standard error. Jurisdiction represents the mean of all sites combined. - - - Notes scale change.

3.11 Trends over Time

3.11.1 Native Fish Species Richness and Native Fish Species Richness Ratio

No significant trend in native fish species richness was detected between the three RWMP sampling periods: 2001-2003, 2004-2006 and 2007-2009 when combining the data from all sites across the TRCA jurisdiction or by watershed. However, visual inspection of the data suggests slight but consistent increases in the native fish species richness in the Humber River, and Carruthers Creek watersheds (Figure 11). This trend may become significant in the future as restoration activities, barrier removal or other improvements to the watershed continue to be implemented.

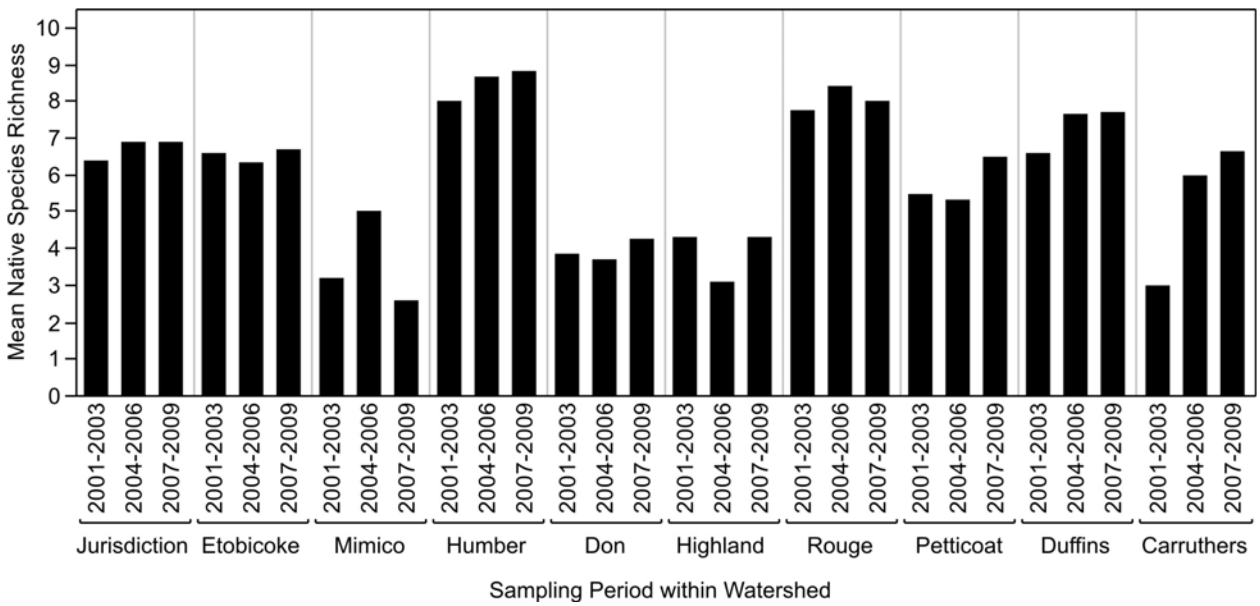

Figure 11: Mean native fish species richness per sampling period within each watershed. Jurisdiction represents the mean native fish species richness across all watersheds combined.

Similarly to the native fish species richness, no significant difference in the observed to expected native fish species richness ratio was detected. In general the RWMP sampling documented approximately 60% of the native fish species that would be expected throughout the jurisdiction. The native fish species richness ratios between the watersheds and sampling years vary when examining the data among the individual watersheds per sampling period. Of all the watersheds, the Rouge River showed the highest ratio for all three sampling years followed by the Duffins Creek and then the Humber River watershed (Figure 12).

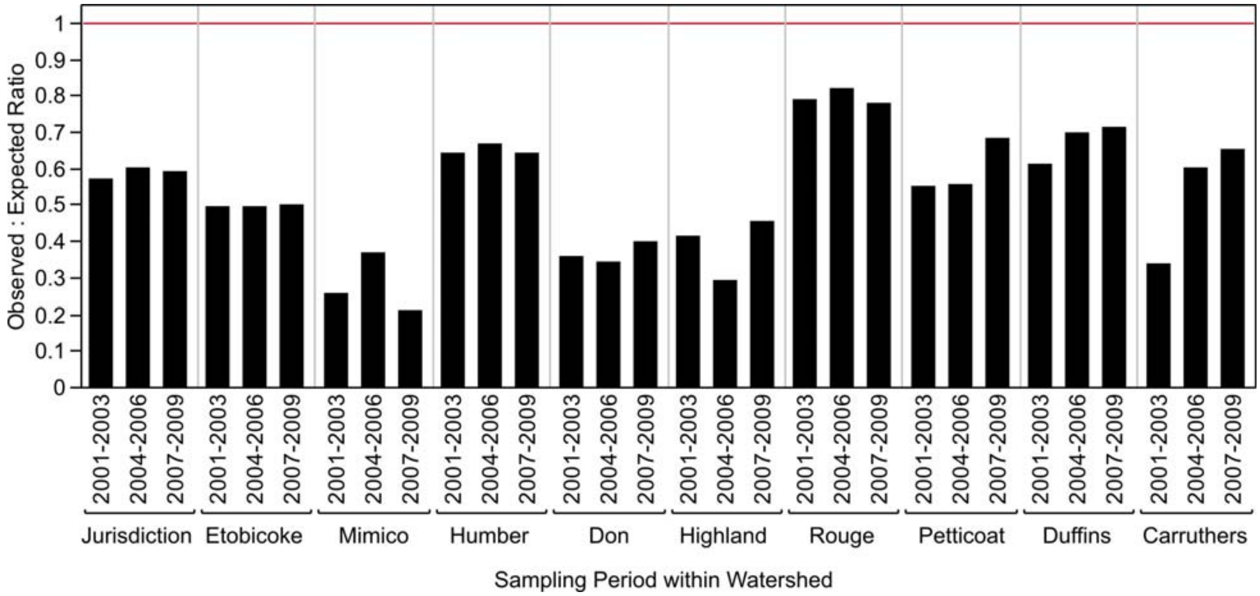

Figure 12: Mean observed to expected native fish species richness per sampling period within each watershed. Jurisdiction represents the mean native fish species richness across all watersheds combined. Red line indicates desired ratio or the ratio one should observe if all habitat and water quality conditions were ideal and all expected native fish species were present.

3.11.2 Index of Biotic Integrity

Similar to the native species richness, no significant difference in the mean IBI score was detected between the three RWMP sampling periods across the TRCA jurisdiction or within a watershed (Figure 13). However, visual inspection of the data suggests consistent increases in the mean IBI score within the Carruthers Creek watershed and slight increases in the mean IBI score across the Jurisdiction and within the Etobicoke Creek and Don River watersheds. These trends may become significant over time.

In general, the mean IBI score for the Jurisdiction and within each watershed were in the good or fair category during all sampling periods. However, as the range of the data suggests, there are RWMP sites that have IBI scores that are either very poor or good (Figure 13). If the IBI score increased significantly one should also observe an increase in native species richness. Currently, the lowest IBI scores were attributed to the Mimico Creek, Don River, and Highland Creek watersheds. These watersheds also had low values of mean native species richness (Figure 11) and are generally associated with higher levels of urbanization. The highest IBI scores were in the Humber River, Rouge River and Duffins Creek watersheds. Similarly these watersheds also had the greatest values of mean native species richness and were considered to be ≈ 1/3 urbanized. Carruthers Creek also received a rather high IBI score in 2009 (sampling period of 2007-2009) however, this should be interpreted with caution since the mean IBI score, as well as the other data analyzed for the Carruthers Creek watershed was based on only three RWMP sampling locations.

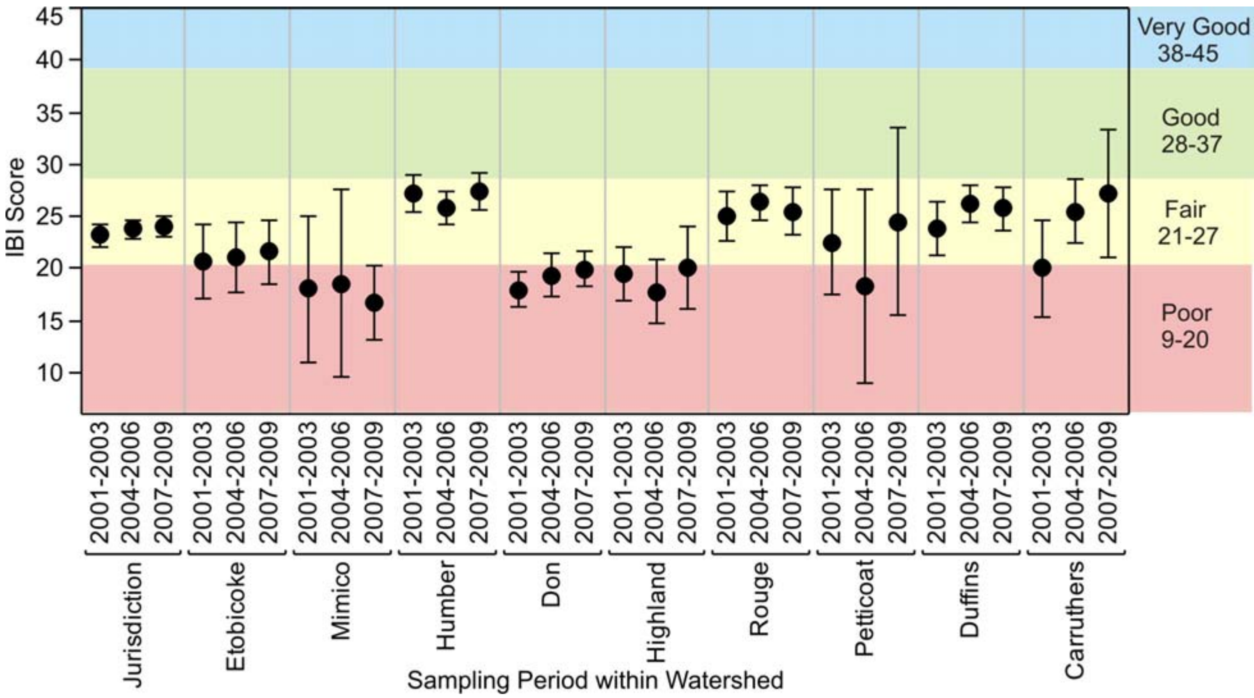

Figure 13: Mean IBI score per sampling period within each watershed. Jurisdiction represents the mean IBI score across all watersheds combined. Error bars represent the standard error. Overlapping error bars indicate lack of significant difference between sampling periods.

3.11.3 Catch per Unit Effort and Biomass per Unit Effort

A significant increase in the mean CPUE and BPUE between the three sampling periods was detected when combining the data across all sites within the jurisdiction (Figure 15 and Figure 15) The Highland Creek watershed showed a significant increase in CPUE but not BPUE. The opposite was true for the Rouge River watershed. No other significant trends in either metric were detected. For specific p values associated with the CPUE and BPUE temporal trends please refer to Appendix A4.

Although most watersheds showed no significant difference among sampling periods, certain non-significant trends within watersheds appeared when inspecting the data visually. These trends showed slight increases in CPUE and BPUE with more recent sampling periods with the exception of Petticoat Creek which showed a decreasing trend (Figure 15 and Figure 15) in both metrics and the Etobicoke and Mimico Creek watersheds which showed a decrease in mean BPUE. Variation in both CPUE and BPUE is expected as fish populations experience natural variation in year class strength. However, this natural variation in CPUE and BPUE has to be continuously monitored in order to be able to recognize when a fish population is changing outside of its normal yearly variation.

In general, the fish species that most contributed to the significant increase in mean CPUE and BPUE were the Longnose Dace, Blacknose Dace, Johnny Darter, Rainbow Darter, Common Shiner, Bluntnose Minnow, Fathead Minnow, and the Fantail Darter (Listed from most to least abundant during the 2007-2009 sampling period). Each of these species had an increase in abundance from 2001-2009 (Appendix A1). Results vary between watersheds however, these eight fish species were always part of the species that experienced an increase in abundance. The significant increase in mean CPUE within the Highland Creek watershed was a result of the increase in abundance of mainly the Bluntnose Minnow but also the Fathead Minnow, Brook Stickleback, and the Sand Shiner. The significant increase in the mean CPUE within the Rouge River was attributed to mainly the increase in abundance of the Longnose and Blacknose Dace, Johnny Darter, Rainbow Darter, but also the Brook Stickleback, and Mottled Sculpin. The Mimico Creek watershed experienced a rather higher CPUE and BPUE during 2005 (sampling period 2004-2006) (Figure 15 and Figure 15), which was a result of an increased capture of White Sucker (Appendix A) during 2005. The decrease in mean CPUE and BPUE (Figure 15) within the Petticoat Creek watershed was a result of the decrease in abundance of the Blacknose Dace and the Creek Chub (Appendix A1). These species were also responsible for the large peak in CPUE of coolwater, native, generalists feeders, and *Cyprinidae* during 2002 (sampling period 2001-2003) in the Petticoat Creek watershed (Figure 16 to Figure 19).

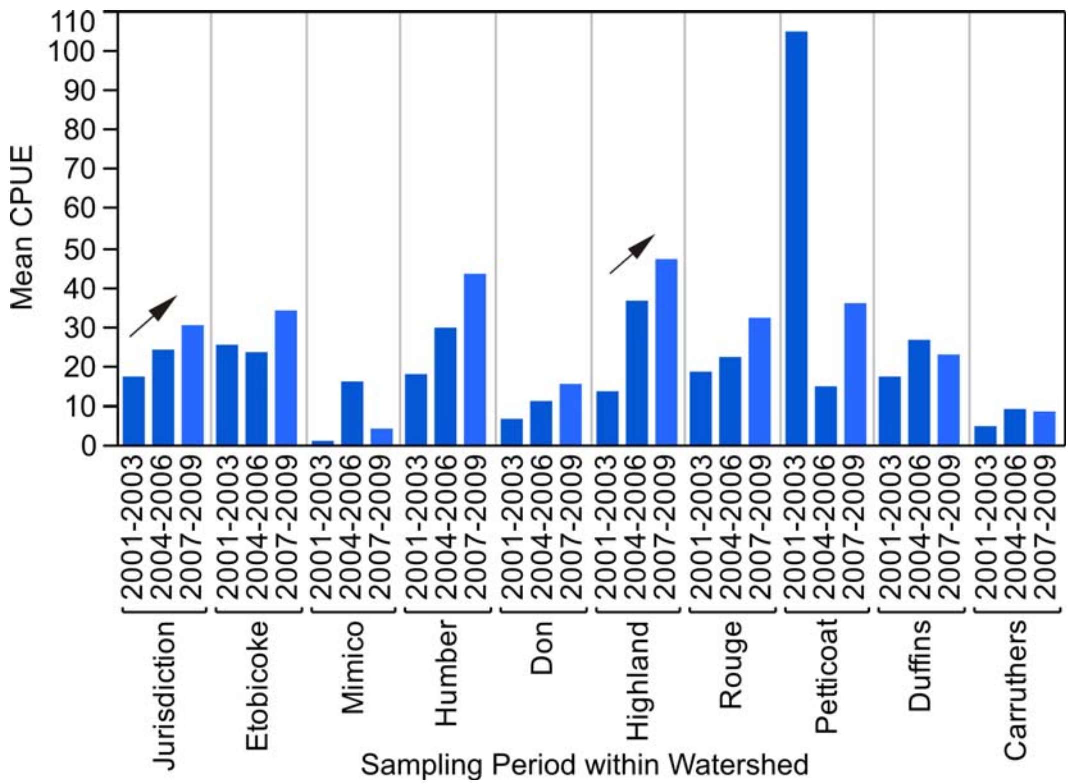

Figure 14: Mean BPUE per watershed per sampling period. Jurisdiction represents the mean BPUE across all watersheds combined. Arrows represent a statistically significant trend in the direction of the arrow.

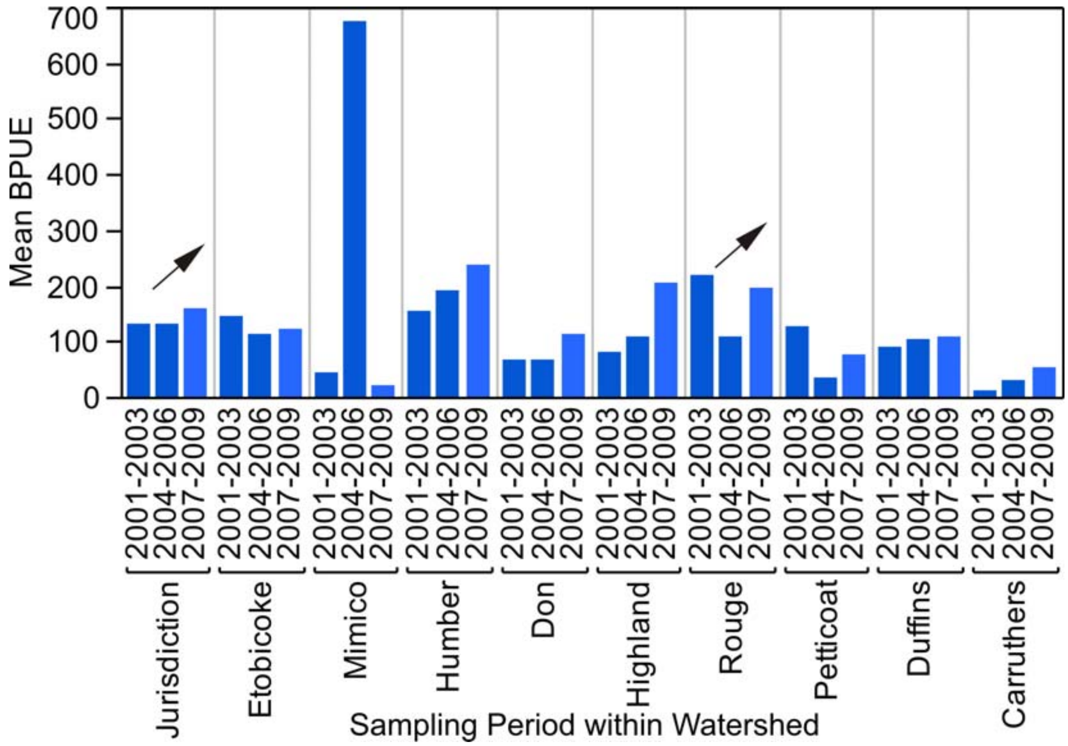

Figure 15: Mean BPUE per watershed per sampling period. Jurisdiction represents the mean BPUE across all watersheds combined. Arrows represent a statistically significant trend in the direction of the arrow.

3.11.4 CPUE and Thermal Regime

When broken down by thermal guild, CPUE revealed that coolwater species had significantly increased during 2001 to 2009 across the jurisdiction and specifically in the Rouge River watershed (Figure 16). Visual inspection of the data suggests increases (non-significant) in the mean CPUE of coolwater fish species over time in the Humber River, Don River, and Highland Creek watersheds (Appendix A4). These trends were mainly due to the increase in abundance of one or a combination of the following fish species; Blacknose Dace, Longnose Dace, Creek Chub, White Sucker, Johnny Darter, Rainbow Darter, and Common Shiner. No significant trend was found in the mean CPUE of warmwater fish species either across the jurisdiction or by watershed. Visual inspection of the data suggests slight increases (non-significant) in the mean CPUE of warmwater fish species over time in the Mimico Creek and Humber River watersheds and across the TRCA's jurisdiction (Figure 16). This was mainly due to the increase in abundance of the Bluntnose Minnow and Fathead Minnow. The mean CPUE of coldwater species significantly increased over time only in the Duffins Creek watershed (Figure 16). This was due to the increase in abundance of Rainbow Trout. No significant difference in the mean CPUE of cold species was detected for the other watersheds or for the jurisdiction. No visual trends in the mean CPUE of cold water species were detected. To view specific *p* values associated with the described mean CPUE per thermal regime trends please refer to Appendix A4.

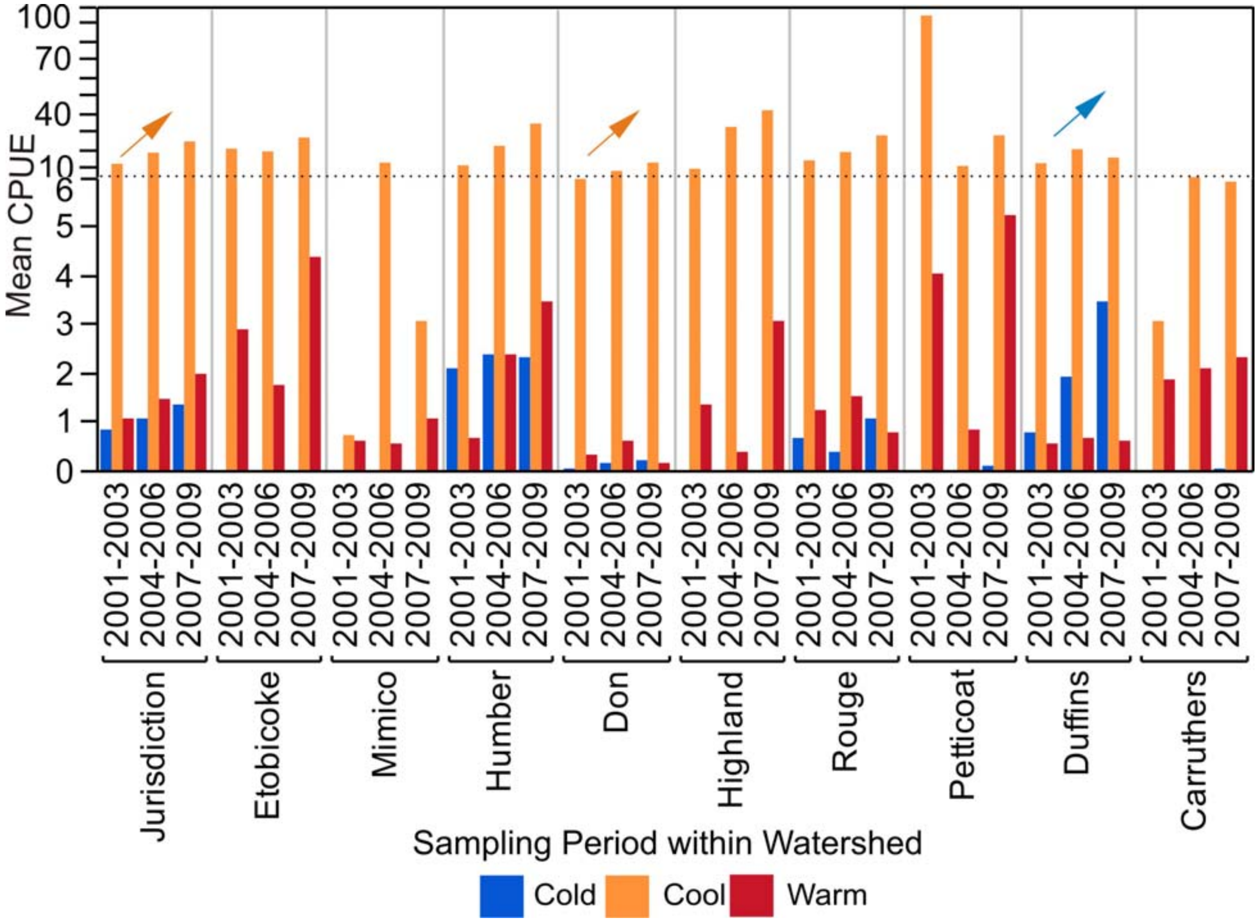

Figure 16: Mean CPUE categorized by thermal guild per watershed per sampling period. Jurisdiction represents the mean CPUE across all watersheds combined. Arrows represent a statistically significant trend in the direction of the arrow. Colors of the arrows refer to the legend. - - - Notes scale change.

3.11.5 CPUE and Fish Origin

When broken down by origin categories, the analysis revealed that the CPUE of native species has significantly increased during 2001 to 2009 in the jurisdiction as a whole and in the Don River, Highland Creek and Rouge River watersheds (Figure 17). Visual inspection of the data suggests slight, but non-significant increases in the mean CPUE of native fish species over time in the Humber River and Don River watersheds (Figure 17 and Appendix A4). The fish responsible for these trends are the 12 most abundant fish found within the TRCA jurisdiction as shown in Table 3. The mean CPUE of native fish species was also significantly greater than that of invasive, non-native, or stocked species (Figure 17)

No significant difference was found in the mean CPUE of invasive species between the three sampling periods (2001-2003, 2004-2006, 2007-2009) in the TRCA jurisdiction or within each watershed. However, Etobicoke Creek, Mimico Creek, Humber River and Duffins Creek showed higher CPUE of invasive species captured in the sampling period of 2007-2009 compared to the two other sampling periods (Figure 17) but, the trends were not significant (Appendix A4). The Highland Creek watershed showed the reverse trend as it had a larger mean CPUE of invasive species in 2001-2003 compared to the other two sampling periods. This was attributed to the decrease in abundance of Goldfish and the Common Carp during the 3 sampling periods (Appendix A1).

The increased CPUE of invasive species in the Humber River during 2007-2009 was attributed to the capture of the Round Goby during 2007 sampling at site HU003WM. Prior to the 2007-2009 sampling, the Round Goby had not been captured in the Humber River watershed (Appendix A1). In Etobicoke Creek, Mimico Creek and Duffins Creek the capture of the Round Goby during the 2007-2009 sampling period (not captured in 2001 or 2004 in Etobicoke Creek, 2002 or 2005 in Mimico Creek, and 2003 or 2006 in Duffins Creek) was also responsible for the increase in CPUE of invasive species (Figure 17). To view specific *p* values associated with the temporal trends of mean CPUE per origin category please refer to Appendix A4.

Visual inspection of the data suggested an increase in the mean CPUE of non-native fish in the Etobicoke Creek and Mimico Creek watersheds (Figure 17). This was attributed to the increase in abundance of the Central Stoneroller. Visual analysis of data also suggests an increase in the mean CPUE of stocked species in the Duffins Creek watershed (Figure 17). This was mainly due to the increase in abundance of the Rainbow Trout. To view specific abundance values per fish species per sampling year please refer to appendix A1.

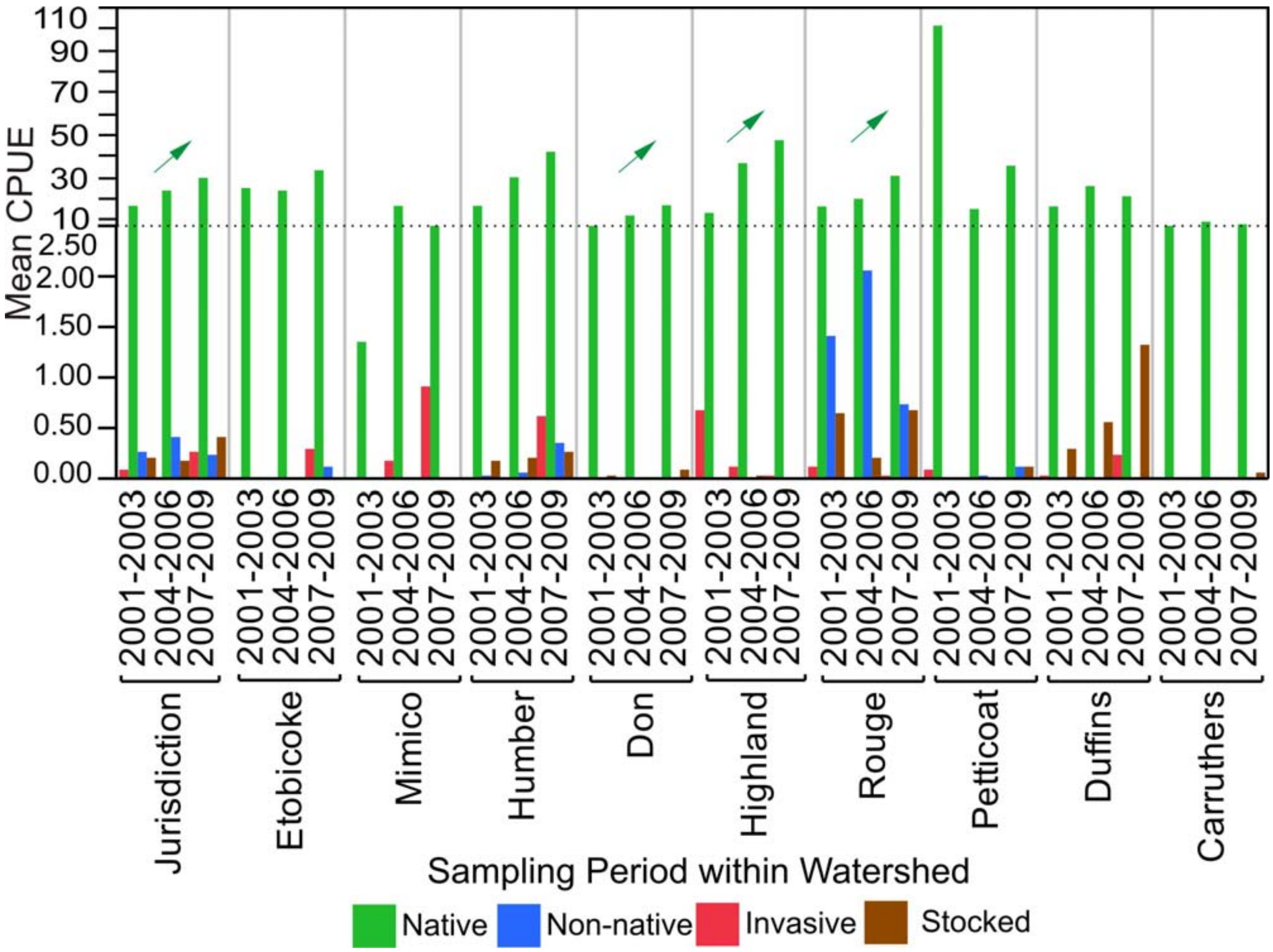

Figure 17: Mean CPUE categorized by origin category per watershed per sampling period. Jurisdiction represents the mean CPUE across all watersheds combined. Arrows represent a statistically significant trend in the direction of the arrow. Colors of the arrows refer to the legend. - - - Notes scale change.

3.11.6 CPUE and Trophic Guild

When broken down by trophic guild, CPUE revealed a significant increase across the jurisdiction in generalist, benthic insectivore, and benthic invertivore type feeders (Figure 18). A significant decrease in the mean CPUE of parasitic filter feeders was also detected (Figure 18). A decrease in parasitic filter feeders was also observed in the Rouge River and Duffins Creek watersheds however, these trends were not significant (Figure 18). This decrease was mainly attributed to the decrease in abundance of the Sea Lamprey which was not captured by the RWMP in any other watershed apart from the two mentioned above (Appendix A1). The reduced abundance of Sea Lamprey was attributed to the continuing implementation of sea lamprey control. This included either the use of lampricides, the building of Sea Lamprey barriers, such as that in Duffins Creek, and adult live trapping of Sea Lampreys.

The mean CPUE of generalists significantly increased in the Don River and Highland Creek watersheds (Figure 18). The increase in abundance of Blacknose Dace, White Sucker, Creek Chub and Fathead Minnow were mainly responsible for this trend (To view specific abundance values per fish species per sampling year refer to appendix A1). The mean CPUE of benthic insectivores and water column insectivores significantly increased in the Rouge River watershed during the 2001-2009 sampling periods (Figure 18), due to the increase in abundance of the Rainbow Darter and the Johnny Darter (Fantail Darter was also responsible for this trend when combining data across our Jurisdiction) (Figure 18 and Appendix A1). The increase in CPUE of water column insectivores was mainly due to the increased abundance of the Brook Stickleback. The Etobicoke Creek watershed also revealed a significant increase in the mean CPUE of benthic herbivores (Figure 18). This was mainly attributed to the increase occurrence of the Central Stoneroller (Appendix A1). The mean CPUE of carnivores was shown to significantly increase in the Duffins Creek watershed (Figure 18). This was attributed to the increased abundance of Rainbow Trout (Appendix A1). To view specific *p* values of temporal trends associated with the mean CPUE per feeding guild please refer to Appendix A4.

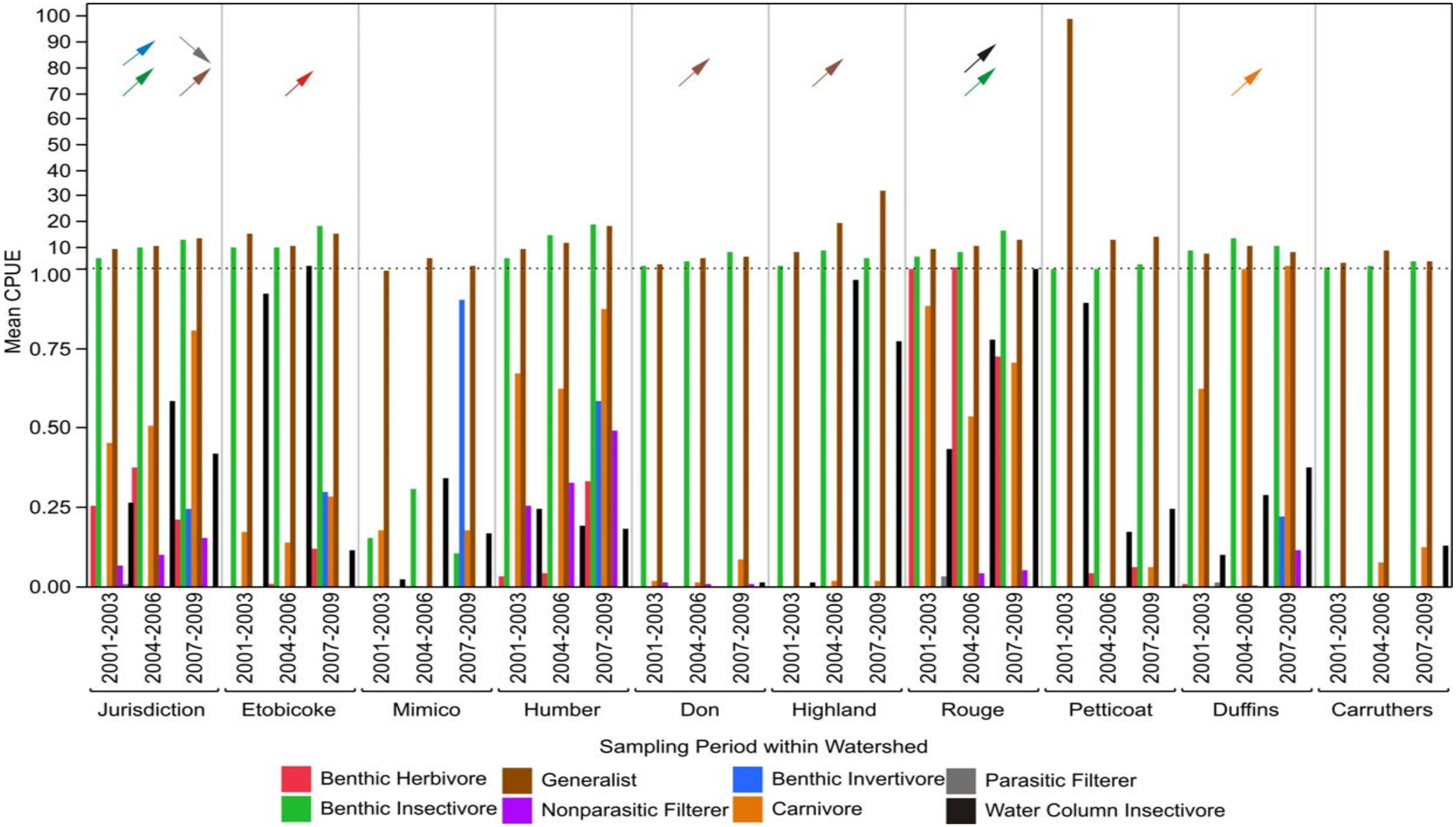

Figure 18: Mean CPUE categorized by feeding guild per watershed per sampling period. Jurisdiction represents the mean CPUE across all watersheds combined. Arrows represent a statistically significant trend in the direction of the arrow. Colors of the arrows refer to the legend. - - - Notes scale change.

3.11.7 CPUE and Fish Family

When broken down by family, CPUE revealed that the number of individual fish belonging to the *Cyprinidae* family significantly increased during 2001 to 2009 across the jurisdiction and in the Mimico Creek and Don River watersheds (Figure 19). The Humber River, Highland Creek, and Rouge River watersheds showed a non-significant increase in the mean CPUE of fish belonging to the *Cyprinidae* family (Figure 19). The large abundances of the Blacknose Dace, Longnose Dace, Creek Chub, and Common Shiner were responsible for the increase in the mean CPUE of *Cyprinidae* (To view specific abundance values per fish species per sampling year please refer to appendix A1). The *Gobiidae* family also showed a significant increase on a jurisdictional scale. This was solely attributed to the increase in abundance of the Round Goby (Appendix A1) specifically within the Etobicoke Creek, Mimico Creek, Humber River, and Duffins Creek watersheds. During the 2007-2009 sampling period the Round Goby was only captured at the first RWMP site directly upstream from the river mouth.

The mean CPUE of *Percidae* significantly increased during 2001 to 2009 in the Rouge River watershed. A non-significant increase of *Percidae* was also observed in the Mimico Creek, Humber River, and Carruthers Creek watersheds and across the jurisdiction (Figure 19). The increase in the mean CPUE of the *Percidae* family was attributed to the increased abundance of the Rainbow Darter, Johnny Darter, and Fantail Darter (Appendix A1). Also, a significant decrease of *Centrarchids* was observed in the Rouge River watershed (Figure 19). This was a result of a decrease in abundance of the Rock Bass and Pumpkinseed (Appendix A1). The opposite, but non-significant trend was observed in the Carruthers Creek watershed. The increase in abundance of the Pumpkinseed was responsible for this visual trend in increasing CPUE of *Centrarchidae*. The Duffins Creek watershed showed a significant increase in the mean CPUE of fish belonging to the *Salmonidae* family (Figure 19). This was attributed to an increase in the abundance of Rainbow Trout. It is also interesting to note that as the abundance of Rainbow Trout increased in the Duffins Creek watershed the abundance of Brown Trout and Brook Trout has decreased. This pattern between the Rainbow Trout and the two other trout species was also present in the Rouge River and Humber River watershed sites (appendix A1). To view specific *p* values associated with the described mean CPUE temporal trends per family please refer to Appendix A4.

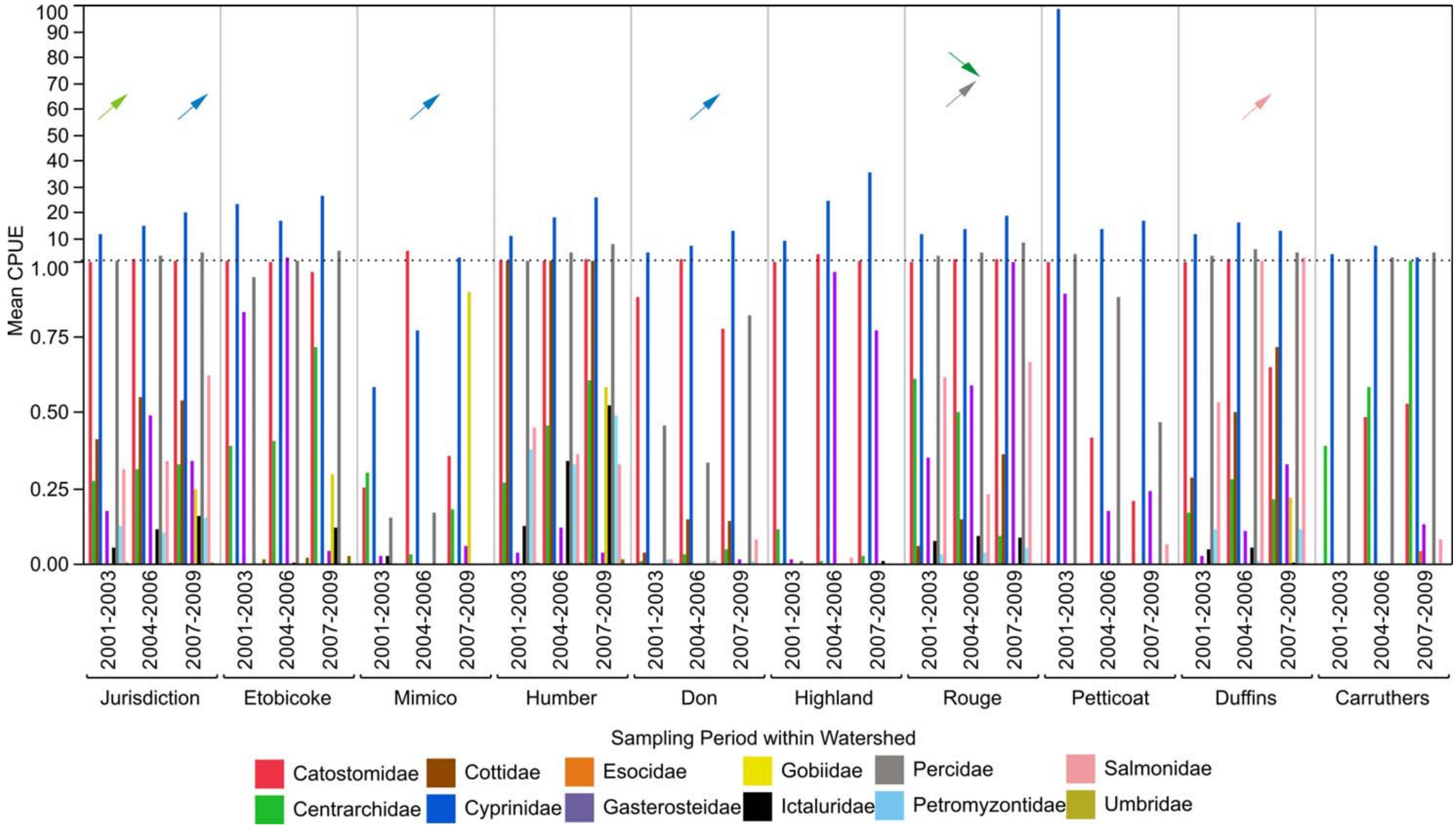

Figure 19: Mean CPUE by family guild per watershed per sampling period. Jurisdiction represents the mean CPUE across all watersheds combined. Arrows represent a statistically significant trend in the direction of the arrow. Colors of the arrows refer to the legend. - - - Notes scale change.

3.12 Relationships with Urbanization

Metrics such as native species richness, the IBI, and CPUE are often used as indicators of the current state of fish biodiversity and the overall health of the fish community. Summarizing such data over time and between watersheds provides useful information on how the fish community is changing and can even be used to foreshadow how the community will likely continue to change. In order to investigate how different degrees of urbanization influence the fish communities found within the region's watersheds, several metrics, such as native fish species richness, IBI score, and CPUE were looked upon in order to see if and how they change between different degrees of road density. Road density was used to approximate the influence of urbanization. The assumption was made that as urbanization of a sub-catchment increases so does the road density.

3.12.1 Native Fish Species Richness

In general native fish species richness and the observed to expected native fish species richness ratio decreased from north to south in every watershed (Figure 4). As illustrated in Figure 20 and Table 4, native fish species richness significantly decreased as road density increased. Based on the regression analysis (Figure 20), an increase of two kilometers of road per km^2 of area represented a loss of approximately 1.04 native fish species. The change from a low road density of 2.70 km/km^2, to a high road density 13.31 km/km^2 resulted in a loss of native species richness by approximately 54% (Table 4).

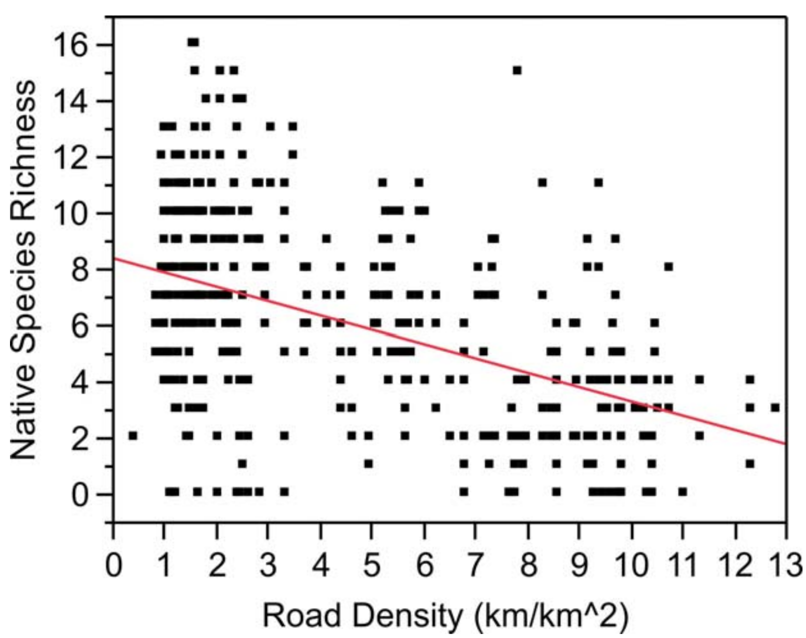

Figure 20: Regression analysis of native species richness vs. Road Density (km/sqr.km). $p < 0.0001$ $R^2adj = 0.22$, $N = 419$, Native Species Richness = 8.04 – 0.51 * Road Density.

Table 4: Results of Wilcoxon test: Calculated mean of metric compared to road density score (1-5) and road density (0-13.31 km/km^2). Trend column shows the trend of the metric with increasing road density. Blank trend indicates lack of trend. Darker hues of blue indicate greater mean value per metric.

	Mean CPUE by Road Density Score and (Road Density Km/Km^2)					
	1	2	3	4	5	
	(0-2.70)	(2.71-5.34)	(5.35-8.02)	(8.03-10.6)	(10-7-13.31)	Trend
Mean Species Richness	8.19	7.46	5.11	4.17	3.78	Decrease
Mean IBI Score	27.03	22.44	20.13	18.9	23.22	Decrease
Mean CPUE	24.45	38.2	15.78	18.15	14.9	Decrease
Mean BPUE	139.87	221.78	113.75	99.08	52.76	Decrease
Mean CPUE of Coldwater	2.14	0.15	0.36	0.04	0	Decrease
Mean CPUE of Coolwater	20.16	35.28	14.39	16.74	14.48	Decrease
Mean CPUE of Warmwater	1.72	2.13	0.93	1.09	0.38	Decrease
Mean CPUE of Native	22.98	36.9	15.26	17.68	14.74	Decrease
Mean CPUE of Non-native	0.57	0.27	0.01	0	0	Decrease
Mean CPUE of Invasive	0.03	0.37	0.09	0.15	0.11	
Mean CPUE of Stocked	0.44	0.03	0.32	0.04	0	Decrease
Mean CPUE Benthic Herbivore	0.55	0.27	0.01	0	0	Decrease
Mean CPUE of Benthic Insecitvores	9.13	22.66	7.39	5.52	6.87	Decrease
Mean CPUE Benthic Invertivore	0.02	0.35	0.07	0.06	0	
Mean CPUE of Carnivores	1.11	0.12	0.42	0.07	0	Decrease
Mean CPUE of Generalists	12.36	14.01	7.34	12.09	5.89	Decrease
Mean CPUE Nonparasitic Filterer	0.23	0.02	0	0	0	Decrease
Mean CPUE Parasitic Filterer	0.01	0.003	0	0	0	Decrease
Mean CPUE Water Column Insectivore	0.57	0.22	0.45	0.13	2.09	
Mean CPUE Catostomidae	1.74	1.82	0.98	2.11	2.26	
Mean CPUE of Centrarchidae	0.49	0.21	0.2	0.12	0.04	Decrease
Mean CPUE of Cottidae	1.1	0.09	0.04	0	0	Decrease
Mean CPUE Cyprinidae	14.46	28.51	13.47	15.93	10.51	
Mean CPUE Esocidae	0.0007	0	0	0	0	
Mean CPUE Gasterosteidae	0.43	0.21	0.39	0.08	2.09	
Mean CPUE Gobiidae	0.02	0.35	0.07	0.06	0	
Mean CPUE Ictaluridae	0.06	0.53	0.04	0.002	0.01	
Mean CPUE of Percidae	4.82	6.7	1.27	0.45	0	Decrease
Mean CPUE of Petromyzontidae	0.27	0.02	0	0	0	Decrease
Mean CPUE of Salmonidae	0.82	0.04	0.31	0.04	0	Decrease
Mean CPUE Umbridae	0.01	0.00	0	0	0	
Mean CPUE Unknown	0.05	0.05	0	0.01	0.03	

Based on presence absence data, sites with road density scores of 12 and 13 only had four native fish species present; Blacknose Dace, Longnose Dace, Creek Chub, and White Sucker (Figure 21). The greatest decrease in native fish species occurred at road density scores of 10 to 12 (road density of 9-12 km/km^2) (Figure 21).

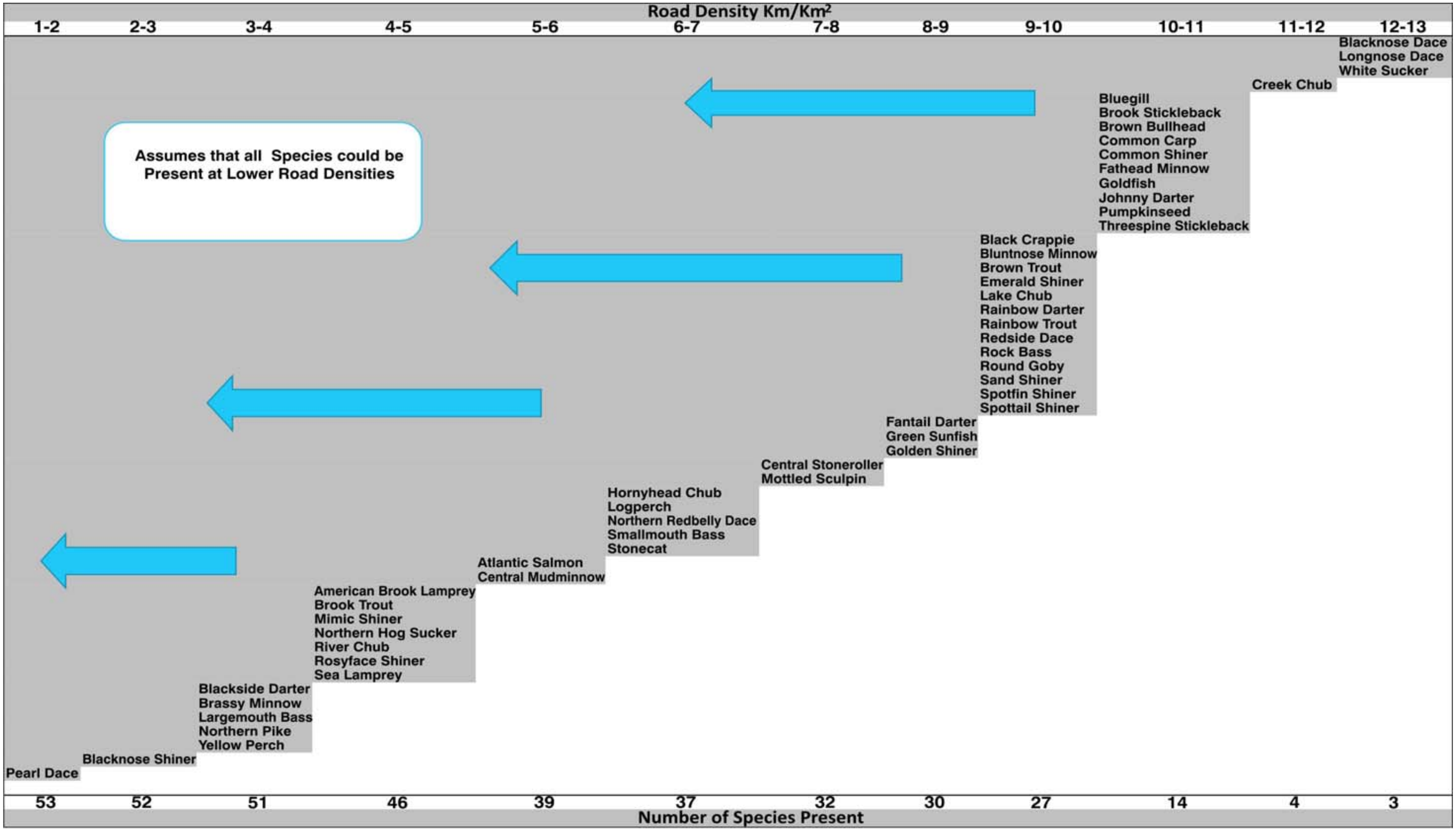

Figure 21: Number of fish species (abundance) present at different road densities and road density scores. Abundance values are the same as those shown in Table 3.

ANCOVA analysis revealed that native fish species richness was significantly different between stream orders when road density was statistically controlled (Figure 22). More importantly, native fish species richness decreased with an increase in road density in all stream orders with the exception of streams of order six. However, the regression line based on data associated with streams of order six was based on a sample size of five and hence was thought to be insufficient to support the overall pattern of decreasing native fish species richness with an increase in road density as depicted in Figure 20 and as shown by all other stream orders during the ANCOVA (Figure 22). With the exception of stream order six, all stream orders showed the same overall decreasing pattern of native fish species richness with an increase in road density. In the case of stream of order six it is suggested that more data is needed to produce a more precise relationship between road density and native fish species richness that is specific to fish species living in streams of higher stream order.

The ANCOVA (Figure 22) showed that road density and stream order accounted for 43.63% of the variation observed in native fish species richness when including the affect of stream order. This was almost double the variation explained when compared a simple regression analysis (Figure 20). However, both the regression analysis and the ANCOVA showed the same general negative trend between native fish species richness and road density.

The significant difference in species richness between stream orders was expected as per the river continuum concept (Vannote *et al.* 1980). According to this concept larger streams should have a more diverse biotic community compared to smaller ordered streams. The response in community change is reflective of the change in stream habitat, channel morphology, stream thermal conditions, and detritus loading. Larger streams typically can support a greater biomass of biota as they accumulate nutrients from head waters. However, the biota in head waters is expected to be different compared to lower reaches of the same lotic system as habitat conditions change from head waters to lower reaches. Aside from headwaters being expected to have a different aquatic community typically less biodiverse compared to lower reaches, headwaters are also thought to be more dependent on energy inputs from the surrounding terrestrial environment (Vannote *et al.*1980). Therefore, the same change in road density indicating a change in land use would have a greater impact on headwater reaches compared to lower reaches which are more directly dependent on energy being transferred from headwaters than the energy inputs from the surrounding terrestrial habitat. Hence, higher ordered streams are typically described as being autotrophic while headwater streams are typically described as being heterotrophic (Vannote *et al.*1980).

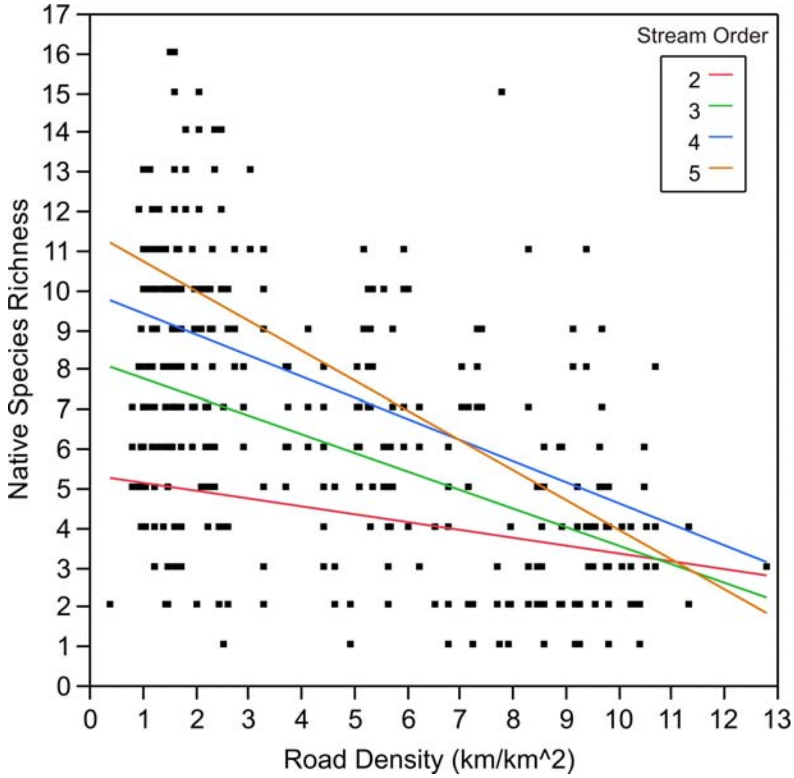

Figure 22: ANCOVA results using a separate slopes model of native fish species richness vs. road density and stream order. Numbers and colors of lines represent stream order.

3.12.2 Index of Biotic Integrity

Similar to native species richness, the IBI score significantly decreased with an increase in road density (Figure 23). Regression analysis revealed that road density was responsible for 28% of the variation observed in the IBI score (Figure 23). As shown by Table 4, with every one increase in road density score the IBI score decreased on average by 0.95 (± 3.28 ST Dev). The difference in IBI values associated with a road density of 2.7 km/km^2 and 13.31 km/km^2 was 3.81. The increase in IBI score from a road density score of four to five (Table 4) was attributed to the affect of lake based species being present at some of the RWMP sites located near the lake that lack barriers to migration (Figure 4). This coupled with a small sample size of points with a road density score of five resulted in a higher IBI score at a road densities of 10.7 and greater compared to that of road densities of 10.69 and less than 10.69.

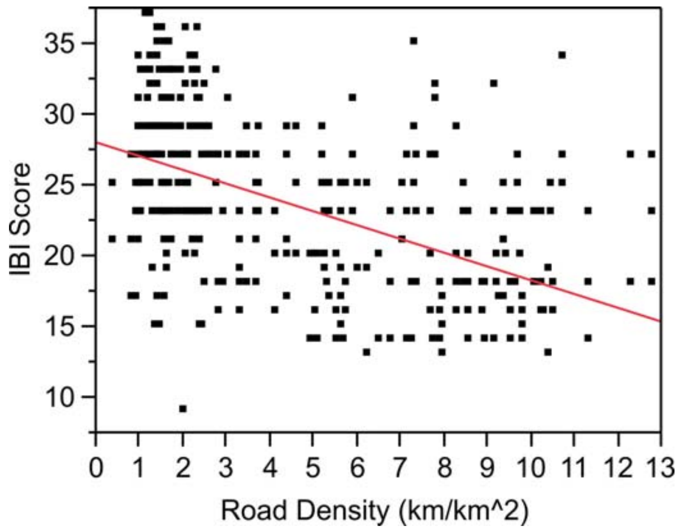

Figure 23: Regression analysis of IBI score vs. Road Density (km/sqr.km). $p < 0.0001$ $R^2adj = 0.28$, N = 386, IBI Score = 27.97 – 0.968 * Road Density.

Similar to native fish species richness, ANCOVA revealed that the IBI score was significantly different between stream orders when road density was statistically controlled (Figure 24). Unlike native fish species richness, the IBI score decreased with an increase in road density in all stream orders. Road density explained 31.01% of the variation observed in the IBI score when including the affect of stream order (Figure 24). Both the regression analysis (Figure 23) and the ANCOVA (Figure 24) showed the same general trend of decreasing IBI score with increasing road density. These results were expected as native fish species richness was part of the IBI function hence, the two are correlated and should show similar results. An interesting observation was that although native fish species richness increased with increasing stream order (TRCA 2011A), ANCOVA analysis revealed that lower ordered streams, two, three, and four, tended to have higher IBI scores compared to larger ordered stream such as those of order five or six. This was interesting because native fish species richness positively influences the IBI score hence a decrease in native fish species richness should result in a decrease in the IBI score. It is speculated that the decrease in CPUE with road density has a stronger negative effect on the IBI score than the increase of native fish species with increasing stream order. Hence the greater the IBI score in lower order streams despite lower ordered streams having less species richness compared to higher ordered streams.

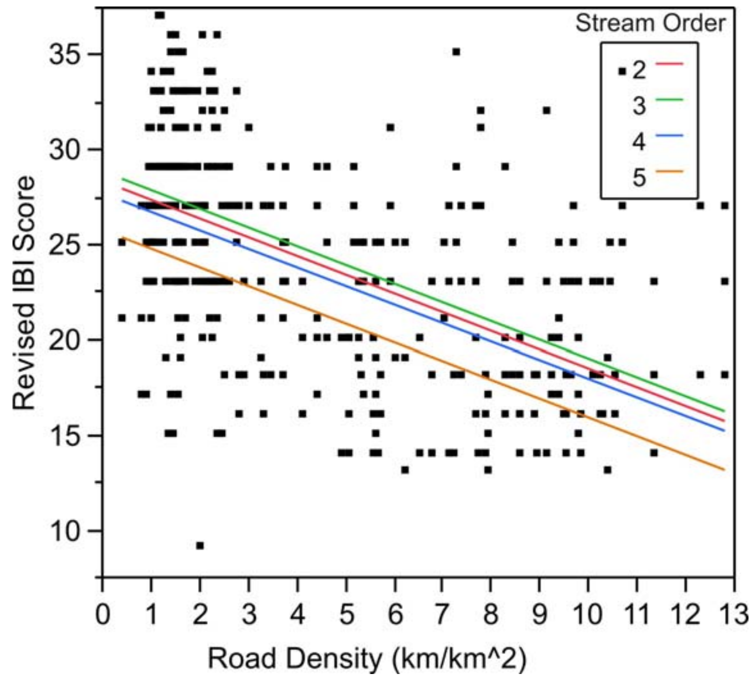

Figure 24: ANCOVA results using an unequal slopes model of IBI score vs. road density and stream order being the categorical variable. Numbers and colors of lines represent stream order.

3.12.3 CPUE and BPUE

CPUE and BPUE were significantly different amongst different road densities. The data suggests that CPUE and BPUE significantly decreased as road density increased (Table 4). Regression analysis showed that the relationship between CPUE and road density was weak although significant.

Road density only explained 1.3% of the variation observed in CPUE. This may be due to the interactions between different families and specific fish species. As the CPUE of one fish family or fish species declined, the CPUE of another family or fish species increased making CPUE appear as it did not change with road density when in fact the loss in CPUE of one family or species was simply being replaced by the gain in another fish species or fish family. Evidence of such fish species substitution appears in the abundance of the Rainbow Trout vs. the abundance of the Brook and Brown Trout abundance data. Beecher *et al*. 1988 also found replacement to occur between salmonid species; Brook Charr, *Salvelinus fontinalis*, and Cutthroat Trout, *Salmo clarki*.

Finally, it is also possible that the relationship between CPUE and road density is not linear but rather dependent on some threshold of road density (as the above road density analysis suggests). Hence the significant result of the ANOVA analysis of CPUE vs. road density score but, weak overall relationship between road density and CPUE as indicated by the regression analysis. The decline in CPUE of certain fish families, trophic guilds, or species may occur once a certain threshold of road density is crossed. Prior to this threshold CPUE may only slightly vary. Further analysis in order to determine such a threshold and where it exists is warranted.

In a review paper on the impacts of roads on aquatic and terrestrial ecosystems, Carnefix and Frissell argue that no truly “safe” threshold of road density exists, and negative impacts begin to be observed at road densities as low as 0.6 km per square km (Carnefix and Frissell. 2001).

3.12.4 CPUE and Fish Family

Mean CPUE per family revealed that the mean CPUE of *Centrarchidae* (Sunfishes)*, Cottidae* (Sculpins), *Percidae* (Perches and Darters), *Petromyzontidae* (Lampreys)*,* and *Salmoninae* (Salmon and Trout) were significantly lower at sites associated with large road densities (Table 4). The other families did not have a significant relationship with road density.

3.12.5 CPUE and Trophic Guild

When grouped by trophic guild, the mean CPUE of carnivores and benthic insectivore’s fish was also significantly different amongst different road densities (Table 4). In general larger road densities showed lower mean CPUE values. The decrease in the mean CPUE of carnivores fish can be explained by the relationship between *Salmonindae* and road density. The majority of the identified carnivores fish were also part of the *Salmonidae* sub family. The majority of fish in the *Salmonidae* family are considered to be coldwater species whose range is limited by the availability and access to cold water refugia. Water temperature often increases as the surrounding landscape becomes more urbanized (Hughes *et al*. 2006) thus decreasing the availability of habitat for coldwater fish such as Brook Trout and Brown Trout which are both carnivores and part of the *Salmonidae sub* family.

The decrease in benthic insectivores fish is hypothesized to be related to the amount and type of benthic insects present at sites with large road densities. The abundance of benthic invertebrates especially insects should decrease in areas where the stream experiences siltation thus changing the benthic habitat. Unless fish can adapt and switch prey items they may become prey limited and choose to leave the habitat in search of one that provides more food.

The mean CPUE of generalists also significantly changed with road density (Table 4). However, the significant difference appeared to be less in magnitude then that of the carnivores and benthic insectivores. This was somewhat expected as fish that are considered generalists are also thought to be more hardy, tolerant fish that are well suited to a variety of conditions and habitats. No other significant differences were found amongst any of the other trophic guilds.

3.12.6 CPUE and Thermal Guild and Fish Origin

Separating CPUE by thermal guild revealed a significantly difference amongst all thermal guilds between different road density scores. CPUE of all thermal guilds was significantly less at higher road densities (Table 4). Similar significant results appeared where found with origin categories with the exception of the CPUE of invasive species. The CPUE of all origin categories appeared to be less at higher road density scores with the exception of invasive species (Table 4).

4. Summary and Conclusions

The nine years of fish community data presented in this report represents the spatial and temporal changes that have occurred and are currently occurring in our fish community across both our entire jurisdiction and in each individual watershed. This report interpreted the collected fish data based on several biological metrics such as catch per unit effort (CPUE), biomass per unit effort (BPUE), native fish species richness, and the index of biotic integrity (IBI score). Such reports help in gauging the current structure of the fish community in our streams and rivers as well as provide an important baseline for future comparisons. Indication of how watersheds compare to each other within our jurisdiction and how they change over time not only sheds light on the current response of our fish community to various influences, but also provides foresight on how our fish community may change in the future as urbanization of our land, habitat modification and destruction, and climate change continue to occur.

Monitoring data from across the TRCA jurisdiction indicated that the Toronto watersheds are comprised of primarily coolwater, native fish species that are generalist feeders or benthic insectivores belonging to the fish family of *Cyprinidae (*Carps and Minnows)*, Percidae* (Perches)*,* or *Catostomidae* (Suckers). The ten most abundant fish species across our jurisdiction were found to be the Blacknose Dace, Longnose Dace, Creek Chub, White Sucker, Johnny Darter, Rainbow Darter, Common Shiner, Mottled Scuplin, Bluntnose Minnow and the Fathead Minnow, with the first four species being significantly more prevalent especially in urbanized areas.

A trend toward an increase in fish catches (based on CPUE) was observed across the jurisdiction as a whole and within specific watersheds which included Etobicoke Creek, Humber River, Don River, Highland Creek, and the Rouge River. However, this trend was only found to statistically significant in the Highland Creek watershed and across the jurisdiction as a whole. Although seemingly positive, this trend in increasing CPUE over time was found to be driven primarily by a handful of species; the ten most abundant species as mentioned above. These species were found to be predominantly coolwater generalists or benthic insectivore and would be considered the most common and tolerant species in urbanized watersheds, with the exception of the Mottled Sculpin which is a cold water invertivore.

A positive note is that invasive species only represented (1%) of the total catch, however a slight increase in this was observed in the last 3 years of monitoring. This was due to the expansion of distribution and abundance of Round Goby, part of the *Gobiidae* family, across the Toronto waterfront and into the lower reaches of the TRCA's watersheds. Overall in the time period of 2001 to 2009 no significant temporal changes in native fish species richness or the IBI score have been observed on a jurisdictional or watershed scale according to the data gathered through the RWMP. This is attributed to the positive resilience of our watersheds despite past and current land use changes.

However, our streams and rivers are showing signs of stress. Variation in native fish species richness and the IBI score was observed spatially throughout the Toronto region with higher richness and IBI scores observed in the Humber River, Rouge River, and Duffins Creek watersheds. Lower than expected species richness was found to be associated with higher urban land use and there was a strong negative correlation observed between urbanization and native fish species richness, the IBI score, and CPUE. Lower species richness was found at sites in watersheds with higher % of urbanized landuse.

Relationships with urbanization were evaluated using road density as a surrogate for the amount of urbanization. The assumption was made that as the level of urbanization increased so did road density. Native fish species richness and the IBI score both significantly decreased with an increase in road density. When statistically accounting for the affect of stream order, native fish species richness and the IBI score differed amongst different stream orders and their magnitude of decrease with an increase in road density was also different between stream orders.

Based on presence absence data, sites with road densities of 11 km/km^2 or greater only had four native fish species present; Blacknose Dace, Longnose Dace, Creek Chub, and White Sucker. The greatest decrease in native fish species occurred at road densities of 9-12 km/km^2.

CPUE and BPUE were also significantly different amongst different road densities. The data suggested that CPUE and BPUE decreased as road density increased. However, not all fish families seemed to be consistent with the overall trend. The CPUE of *Centrarchidae* (Sunfishes), *Cottidae* (Sculpins), *Percidae* (Perches and Darters), *Petromyzontidae* (Lampreys), and *Salmonidae* (Salmon and Trout) were significantly lower at RWMP sites associated with higher road densities. When grouped by trophic guild, the mean CPUE of carnivores and benthic insectivores fish was also significantly different among different road densities. In general higher road density meant lower mean CPUE values.

Similar relationships with urbanization have been reported by a variety of authors some of which used metrics other then road density in order to quantify urbanization (Paul and Meyer, 2001; Brown *et al*. 2005; Stanfield and Kilgour. 2006). Analysis of 9 years of data from the RWMP suggests that the fish communities in the more urbanized portions of Toronto region streams are stressed and a shift in the biological community is imminent. A decline in overall species richness and an increase in tolerant fish species are both symptoms of the urban stream syndrome (Walsh *et al*. 2005). Additional analysis and/or data collection will be needed to help understand the complex interactions of various urban stressors and the specific role that such stressors play in shaping the Toronto and region fish community.

Future data analysis opportunities include monitoring the change in CPUE of tolerant fish species, such as the Creek Chub, Blacknose Dace, Longnose Dace, and White Sucker, as an indicator of urban stress. Monitoring changes in the abundance and distribution of invasive species, such as the Round Goby, non-native species, such as the Central Stoneroller, and sensitive species, such as the Redside Dace. Assessing changes in fish species richness, distribution, and abundance as associated with in stream barriers. Assessing the possible influence and affect that climate change will have on our fish communities by looking at long term shifts in thermal guilds and water temperature. An analysis of stream habitat, channel morphology, water quality data, and hydrological data and their interaction with urbanization is also warranted. Lastly tracking the success of conservation and recovery efforts, such as alternative stocking programs and habitat restoration and how such actions influence the current fish community and ecosystem functioning.

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A1 – Total Fish Captures by Species for TRCA Jurisdiction and by Watershed

Species Common Name	TRCA Jurisdiction			Etobicoke Creek			Mimico Creek			Humber River			Don River		
	2001-2003	2004-2006	2007-2009	2001	2004	2007	2002	2005	2008	2001	2004	2007	2002	2005	2008
American Brook Lamprey	88	98	141							84	87	114	4	2	2
Atlantic Salmon		86	168												
Black Crappie	2	2	2				1								
Blacknose Dace	4409	4481	5223	657	403	485		1		926	894	961	290	392	548
Blacknose Shiner	1		1	1		1									
Blackside Darter	3	15	7							3	15	7			
Bluegill	3														
Bluntnose Minnow	334	510	742	201	107	308				44	320	397	10	1	
Brassy Minnow	4		1							3		1			
Brook Stickleback	177	671	350	60	403	4	1		2	18	62	17			2
Brook Trout	128	103	44							81	62	23			
Brown Bullhead	26	11	18		1	15	1			22	9	2			
Brown Trout	87	62	50							47	59	35	3	1	3
Central Mudminnow	4	5	8	3	3	4				1	2	4			
Central Stoneroller	212	322	182		1	10				8	11	85			
Common Carp	14	9	2					2		1		1	1		
Common Shiner	367	865	1468	6	70	202	2	1		114	583	1133	5	2	2
Creek Chub	2598	2466	2354	222	260	193	3	2	35	1000	643	1070	186	102	204
Emerald Shiner	1		7			5			2	1					
Fantail Darter	155	414	632	6	50	36				149	361	596			
Fathead Minnow	363	574	538	63	82	89	17	3	32	13	79	90	48	122	20
Golden Shiner	238	1	1	72	1					166					
Goldfish	45	1	3											1	1
Green Sunfish	0	43	12		33	5					10	7			
Hornyhead Chub	42	20	9									4			
Johnny Darter	891	1573	2170	95	152	491	6	5		197	518	546	46	53	101
Lake Chub			1						1						
Largemouth Bass	42	19								40	13				
Log Perch	2	5	2								1	1			
Longnose Dace	3161	5015	5733	679	740	1132		4	3	583	1555	1685	439	514	852
Mimic Shiner			1									1			
Mottled Sculpin	552	687	543							478	562	374	9	25	20
Northern Hog Sucker	57	40	125	1						56	40	125			
Northern Pike			1												
Northern Redbelly Dace	63	30	11	26	9					21	2	3			2
Pearl Dace	1	5		1	5										
Pumpkinseed	132	154	107	25	8	15	5	1		17	60	12	1	7	8
Rainbow Darter	761	1118	1513							142	299	532			
Rainbow Trout	153	134	299							8	14	27		1	5
Redside Dace	58	99	52							40	33	25			
River Chub	39	78	183							39	78	183			
Rock Bass	113	100	174	27	18	29	6		5	39	62	129	1		
Rosyface Shiner	3		7							2		7			
Round Goby			164			21			25			96			
Sand Shiner	11	3	36									6			
Sea Lamprey	11														
Smallmouth Bass	18	38	2			1									1
Spotfin Shiner	14	13	5	5				1		2		4			
Spottail Shiner	105	10	4	86				9	1	19		3			
Stonecat	21	72	104							3	54	91			
Threespine Stickleback		5	2												
White Sucker	1200	2380	1173	183	151	118	8	159	10	343	490	482	120	411	97
Yellow Perch		13	1								9	1			

Species Common Name	Highland Creek			Rouge River			Petticoat Creek			Duffins Creek			Carruthers Creek		
	2002	2005	2008	2003	2006	2009	2002	2005	2008	2003	2006	2009	2003	2006	2009
American Brook Lamprey					8	9					1	16			
Atlantic Salmon											86	168			
Black Crappie				1	2	2									
Blacknose Dace	371	620	1353	771	1052	930	891	223	285	491	771	652	12	125	9
Blacknose Shiner															
Blackside Darter															
Bluegill	3														
Bluntnose Minnow	11		2	55	29	8				13	6	2		47	25
Brassy Minnow										1					
Brook Stickleback	1	48	69	81	139	204	11	4	6	5	15	43			3
Brook Trout				2	4					45	37	21			
Brown Bullhead			1		1					3					
Brown Trout				37	1	11					1	1			
Central Mudminnow															
Central Stoneroller				204	309	85		1	2						
Common Carp		5		12	1	1					1				
Common Shiner	1	1	1	185	130	85				54	63	42		15	3
Creek Chub	81	127	59	491	772	431	291	32	26	301	486	308	23	42	28
Emerald Shiner															
Fantail Darter					2						1				
Fathead Minnow	16	16	94	80	190	80	49	17	65	25	44	66	52	21	2
Golden Shiner												1			
Goldfish	41		1	3		1	1								
Green Sunfish															
Hornyhead Chub				41	20	5				1					
Johnny Darter				316	476	697	6	8	5	182	272	209	43	89	121
Lake Chub															
Largemouth Bass				2	2						4				
Log Perch				2	3	1					1				
Longnose Dace	247	464	250	514	673	984	16	23	90	677	1040	737	6	2	
Mimic Shiner															
Mottled Sculpin				12	22	37				53	78	112			
Northern Hog Sucker															
Northern Pike															1
Northern Redbelly Dace				13	19	3				1		3	2		
Pearl Dace															
Pumpkinseed	6	1	1	63	39	7				9	17	20	6	21	44
Rainbow Darter	1			362	382	526		11	9	256	426	446			
Rainbow Trout		1		98	40	78			2	47	78	185			2
Redside Dace				18	59	21					7	6			
River Chub															
Rock Bass			1	36	12	3				4	8	7			
Rosyface Shiner				1											
Round Goby												22			
Sand Shiner	6	1	30	1	1					4	1				
Sea Lamprey				9						2					
Smallmouth Bass				13	32					5	6				
Spotfin Shiner										7	12	1			
Spottail Shiner											1				
Stonecat				14	13	12				4	5	1			
Threespine Stickleback		5	2												
White Sucker	100	320	122	285	567	259	16	10	6	145	258	72		14	7
Yellow Perch					2									2	

A2 - Descriptive Statistics for Index of Biotic Integrity Analysis

Table A2-1 - Descriptive Statistics for IBI Scores

	Jurisdiction	Etobicoke	Mimico	Humber	Don	Highland	Rouge	Petticoat	Duffins	Carruthers
Mean	23.6	21.1	17.5	26.76	19.1	19.07	25.62	20.6	25.29	25.22
Min	9	14	14	15	13	14	13	9	15	17
Max	37	34	32	37	29	34	35	29	37	36
Std Dev	6	6.07	5.71	5.07	4.11	4.76	5.18	7.5	5.01	5.8
Variance	35.95	36.82	32.64	25.72	16.93	22.69	26.88	56.3	25.14	33.69

Table A2-2 - Percentage of Sites in Each Watershed per IBI Category

IBI Stream Quality	Jurisdiction	Etobicoke	Mimico	Humber	Don	Highland	Rouge	Petticoat	Duffins	Carruthers
very good	0	0	0	0	0	0	0	0	0	0
good	23.81	16.67	6.67	41.82	1.47	3.03	31.51	14.29	28.57	22.22
fair	38.57	21.43	13.33	40	27.94	27.27	50.68	14.29	57.14	55.56
poor	32.62	61.9	60	13.64	63.24	51.52	17.81	42.86	14.29	22.22
No fish	5	0	20	4.55	7.35	18.18	0	28.57	0	0

A3 - Descriptive Statistics of CPUE Analysis

Table A3-1: Descriptive statistics of CPUE and BPUE calculated based on all years of sampling (2001-2009) separated by watershed and for the entire jurisdiction.

	Statistics	Jurisdiction	Etobicoke	Mimico	Humber	Don	Highland	Rouge	Petticoat	Duffins	Carruthers
CPUE	Mean	23.57	28.13	5	29.6	11.47	30.87	23.63	46.86	22.5	9.33
	Min	0.13	1.15	0.39	0.74	0.13	0.47	1.81	0.35	2.32	0.68
	Max	253.15	80.91	31.66	253.15	45.77	196.74	84.69	188.68	95.4	24
	Std Dev	31.11	24.09	9.08	44.98	10.83	43.75	17.22	63.73	17.13	7.53
	Variance	967.96	580.13	82.52	2023.06	117.32	1913.73	296.42	4061.96	293.27	56.65
BPUE	Mean	137.65	126.59	141.11	192.93	85.53	106.51	170.69	73.88	103.29	33.58
	Min	0	2.79	0.04	0	0.02	3.28	4.55	0.53	21.43	0.68
	Max	2124.02	450.34	1349.68	1234.4	454.33	455.78	2124.02	190.46	299.3	64.61
	Std Dev	206.06	116.08	386.03	220.87	109.6	122.27	330.16	58.1	68.36	21.25
	Variance	42461.09	13474.12	149020	48783.4	12011.5	14949.37	109008.7	3375.3	4673.26	451.47

Table A3-2: Descriptive statistics of CPUE divided by thermal regime calculated based on all years of sampling (2001-2009) separated by watershed and for the entire jurisdiction.

	Statistics	Jurisdiction	Etobicoke	Mimico	Humber	Don	Highland	Rouge	Petticoat	Duffins	Carruthers
CPUE Coldwater	Mean	1.11	0	0	2.28	0.17	0.01	0.76	0.04	2.07	0.03
	Min	0	0	0	0	0	0	0	0	0	0
	Max	21.39	0	0	17.77	3.18	0.23	10.1	0.26	21.39	0.25
	Std Dev	2.78	0	0	3.85	0.62	0.04	1.85	0.1	3.69	0.08
	Variance	7.74	0	0	14.81	0.38	0	3.41	0.01	13.61	0.01
CPUE Coolwater	Mean	20.59	25	4.16	24.51	10.69	29.15	21.32	42.69	19.5	6.54
	Min	0	0	0	0	0	0	1.81	0.18	1.21	0.68
	Max	227.97	80.35	30.97	227.97	45.77	196.52	81.38	173.24	91.69	19.41
	Std Dev	29.11	23.55	9.05	41.51	10.89	43.66	16.07	58.48	16.27	5.6
	Variance	847.68	554.44	81.85	1723.15	118.57	1905.85	258.14	3419.53	264.68	31.38
CPUE Warmwater	Mean	1.5	2.83	0.81	2.13	0.39	1.68	1.28	3.02	0.65	2.62
	Min	0	0	0	0	0	0	0	0.13	0	0
	Max	33.64	31.8	1.81	33.64	6.56	15.27	9.81	10.12	5.19	7.53
	Std Dev	3.5	5.38	0.54	4.95	0.97	3.58	1.77	4.22	1.1	2.58
	Variance	12.28	28.98	0.29	24.55	0.95	12.81	3.13	17.79	1.2	6.67

Table A3-3: Descriptive statistics of CPUE divided by origin category calculated based on all years of sampling (2001-2009) separated by watershed and for the entire jurisdiction.

	Statistics	Jurisdiction	Etobicoke	Mimico	Humber	Don	Highland	Rouge	Petticoat	Duffins	Carruthers
CPUE Invasive	Mean	0.11	0.1	0.4	0.18	0.01	0.28	0.06	0.02	0.08	0
	Min	0	0	0	0	0	0	0	0	0	0
	Max	18.79	4.2	4.51	18.79	0.22	4.13	1.36	0.16	4.68	0
	Variance	1.11	0.44	1.68	3.33	0	0.78	0.04	0	0.35	0
	Std Dev	1.05	0.66	1.3	1.83	0.04	0.88	0.2	0.06	0.59	0
CPUE Native	Mean	22.5	27.68	4.57	28.39	11.2	30.55	21.19	45.63	21.42	9.16
	Min	0	0.88	0.39	0	0	0.47	1.81	0.35	2.32	0.68
	Max	252.62	79.97	31.32	252.62	45.77	196.52	84.69	181.04	92.62	24
	Variance	908.78	588.26	75.72	1878.03	117.08	1914.98	232.58	3713.72	282.44	55.98
	Std Dev	30.15	24.25	8.7	43.34	10.82	43.76	15.25	60.94	16.81	7.48
CPUE Non-native	Mean	0.31	0.05	0	0.13	0	0	1.59	0.05	0	0
	Min	0	0	0	0	0	0	0	0	0	0
	Max	29.78	0.94	0	7.56	0	0	29.78	0.26	0	0
	Variance	5.02	0.03	0	0.6	0	0	27.23	0.01	0	0
	Std Dev	2.24	0.16	0	0.77	0	0	5.22	0.1	0	0
CPUE Stocked	Mean	0.27	0	0	0.21	0.04	0.01	0.53	0.04	0.72	0.03
	Min	0	0	0	0	0	0	0	0	0	0
	Max	13	0	0	3.95	1.41	0.23	6.23	0.26	13	0.25
	Variance	0.96	0	0	0.3	0.04	0	1.45	0.01	3.55	0.01
	Std Dev	0.98	0	0	0.54	0.19	0.04	1.2	0.1	1.88	0.08

Table A3-4: Descriptive statistics of CPUE divided by trophic guild calculated based on all years of sampling (2001-2009) separated by watershed and for the entire jurisdiction.

	Statistics	Jurisdiction	Etobicoke	Mimico	Humber	Don	Highland	Rouge	Petticoat	Duffins	Carruthers
CPUE Benthic Herbivore	Mean	0.31	0.05	0	0.14	0	0	1.59	0.05	0	0
	Min	0	0	0	0	0	0	0	0	0	0
	Max	29.78	0.94	0	7.56	0	0	29.78	0.26	0.21	0
	Std Dev	2.24	0.16	0	0.77	0	0	5.22	0.1	0.03	0
	Variance	5.02	0.03	0	0.6	0	0	27.23	0.01	0	0
CPUE Benthic Insectivore	Mean	10.04	13.11	0.24	13.69	5.53	7.03	10.06	3.1	11.26	3.32
	Min	0	0	0	0	0	0	0	0	0	0.68
	Max	171.86	60.17	1.54	171.86	37.1	81.04	38.15	13.18	67.19	6.55
	Std Dev	18.77	16.69	0.48	29.87	8.53	16.75	9.87	4.75	12.66	2.09
	Variance	352.38	278.52	0.23	892	72.69	280.56	97.38	22.54	160.36	4.35
CPUE Benthic Invertivore	Mean	0.08	0.1	0.38	0.18	0	0	0	0	0.07	0
	Min	0	0	0	0	0	0	0	0	0	0
	Max	18.6	4.2	4.51	18.6	0	0	0	0	4.68	0
	Std Dev	1.02	0.66	1.3	1.81	0	0	0	0	0.59	0
	Variance	1.03	0.44	1.7	3.26	0	0	0	0	0.35	0
CPUE Carnivore	Mean	0.63	0.19	0.15	0.75	0.04	0.02	0.76	0.04	1.64	0.07
	Min	0	0	0	0	0	0	0	0	0	0
	Max	21.08	2.15	0.9	9.9	1.41	0.23	6.23	0.26	21.08	0.25
	Std Dev	1.73	0.49	0.35	1.38	0.19	0.06	1.26	0.1	3.45	0.11
	Variance	2.99	0.24	0.12	1.91	0.04	0	1.58	0.01	11.88	0.01
CPUE Generalist	Mean	11.58	13.08	3.99	13.58	5.65	23.05	10.08	42.09	8.95	5.76
	Min	0	0	0.39	0	0.13	0.31	0.36	0.35	0.59	0
	Max	179.41	45.39	28.41	106.89	26.65	115.48	42.55	179.41	30.65	18.55
	Std Dev	17.02	11.78	7.87	18.64	5.39	30.67	8.64	61.6	7.18	6.23
	Variance	289.69	138.66	61.88	347.59	29.08	940.55	74.58	3794.04	51.58	38.8
CPUE Nonparasitic Filterer	Mean	0.11	0	0	0.37	0.01	0	0.02	0	0.04	0
	Min	0	0	0	0	0	0	0	0	0	0
	Max	6.74	0	0	6.74	0.39	0	0.78	0	1.69	0
	Std Dev	0.59	0	0	1.08	0.07	0	0.11	0	0.23	0
	Variance	0.35	0	0	1.16	0	0	0.01	0	0.05	0
CPUE Parasitic Filterer	Mean	0	0	0	0	0	0	0.01	0	0.01	0
	Min	0	0	0	0	0	0	0	0	0	0
	Max	0.41	0	0	0	0	0	0.41	0	0.21	0
	Std Dev	0.03	0	0	0	0	0	0.06	0	0.03	0
	Variance	0	0	0	0	0	0	0	0	0	0
CPUE Water Column Insectivore	Mean	0.44	1.3	0.22	0.22	0.01	0.74	0.84	0.47	0.25	0.04
	Min	0	0	0	0	0	0	0	0	0	0
	Max	36.3	36.3	1.71	3.16	0.36	10.34	17.63	1.79	5.44	0.4
	Std Dev	2.3	5.77	0.5	0.5	0.05	2.57	2.68	0.68	0.81	0.13
	Variance	5.29	33.34	0.25	0.25	0	6.61	7.18	0.46	0.66	0.02

Table A3-5: Descriptive statistics of CPUE divided by fish families calculated based on all years of sampling (2001-2009) separated by watershed and for the entire jurisdiction.

	Statistics	Jurisdiction	Etobicoke	Mimico	Humber	Don	Highland	Rouge	Petticoat	Duffins	Carruthers
CPUE Catostomidae	Mean	1.66	1.18	2.52	1.84	1.47	2.73	1.9	0.66	1.26	0.34
	Min	0	0	0	0	0	0	0	0	0	0
	Max	37.58	9.78	27.21	17.92	12.5	37.58	10.86	2.28	19.18	0.93
	Std Dev	3.33	2.07	7.79	2.63	2.56	7.59	2.48	0.8	2.69	0.39
	Variance	11.12	4.27	60.75	6.9	6.54	57.53	6.13	0.63	7.25	0.15
CPUE Centrarchidae	Mean	0.32	0.49	0.22	0.46	0.03	0.07	0.45	0	0.22	0.9
	Min	0	0	0	0	0	0	0	0	0	0
	Max	10.03	2.58	1.53	10.03	0.72	1	5.01	0	1.77	2.51
	Std Dev	0.85	0.8	0.49	1.25	0.12	0.2	0.93	0	0.45	0.9
	Variance	0.73	0.64	0.24	1.56	0.01	0.04	0.87	0	0.2	0.81
CPUE Cottidae	Mean	0.54	0	0	1.52	0.12	0	0.21	0	0.49	0
	Min	0	0	0	0	0	0	0	0	0	0
	Max	15.12	0	0	15.12	2.8	0	7.37	0	3.7	0
	Std Dev	1.88	0	0	3.22	0.46	0	1.06	0	1.01	0
	Variance	3.54	0	0	10.38	0.21	0	1.12	0	1.02	0
CPUE Cyprinidae	Mean	16.29	22.29	1.7	19.18	9.21	27.28	14.03	43.86	13.92	4.78
	Min	0	0	0.39	0	0.13	0.47	0.36	0.35	1.15	0
	Max	216.19	79.41	5.78	216.19	44.57	192.92	48.01	177.14	66.82	17.88
	Std Dev	25.5	21.92	1.7	34.51	10.01	43.01	12.06	59.94	11.54	6.1
	Variance	650.28	480.66	2.89	1191.13	100.14	1849.68	145.51	3592.5	133.26	37.27
CPUE Esocidae	Mean	0	0	0	0	0	0	0	0	0	0.01
	Min	0	0	0	0	0	0	0	0	0	0
	Max	0.13	0	0	0	0	0	0	0	0	0.13
	Std Dev	0.01	0	0	0	0	0	0	0	0	0.04
	Variance	0	0	0	0	0	0	0	0	0	0
CPUE Gasterosteidae	Mean	0.36	1.24	0.04	0.07	0.01	0.74	0.76	0.47	0.16	0.04
	Min	0	0	0	0	0	0	0	0	0	0
	Max	36.3	36.3	0.31	1.42	0.36	10.34	17.63	1.79	5.44	0.4
	Std Dev	2.29	5.8	0.09	0.24	0.05	2.57	2.68	0.68	0.72	0.13
	Variance	5.25	33.68	0.01	0.06	0	6.61	7.17	0.46	0.52	0.02
CPUE Gobiidae	Mean	0.08	0.1	0.38	0.18	0	0	0	0	0.07	0
	Min	0	0	0	0	0	0	0	0	0	0
	Max	18.6	4.2	4.51	18.6	0	0	0	0	4.68	0
	Std Dev	1.02	0.66	1.3	1.81	0	0	0	0	0.59	0
	Variance	1.03	0.44	1.7	3.26	0	0	0	0	0.35	0
CPUE Ictaluridae	Mean	0.12	0.03	0.01	0.34	0	0	0.09	0	0.04	0
	Min	0	0	0	0	0	0	0	0	0	0
	Max	7.85	0.78	0.13	7.85	0	0.12	1.02	0	1.06	0
	Std Dev	0.67	0.14	0.04	1.24	0	0.02	0.21	0	0.15	0
	Variance	0.45	0.02	0	1.54	0	0	0.05	0	0.02	0
CPUE Percidae	Mean	3.56	2.76	0.14	5.06	0.59	0.01	5.63	1.82	4.71	3.22
	Min	0	0	0	0	0	0	0	0	0	0.68
	Max	66.81	29.7	0.86	66.81	9.69	0.14	27.74	7.48	38.17	6.55
	Std Dev	7.05	6.1	0.32	9.99	1.59	0.03	6.36	2.57	6.91	2.08
	Variance	49.68	37.18	0.1	99.8	2.52	0	40.42	6.59	47.68	4.31
CPUE Petromyzontidae	Mean	0.13	0	0	0.42	0.01	0	0.03	0	0.08	0
	Min	0	0	0	0	0	0	0	0	0	0
	Max	6.74	0	0	6.74	0.39	0	0.78	0	2.14	0
	Std Dev	0.62	0	0	1.1	0.07	0	0.12	0	0.35	0
	Variance	0.38	0	0	1.22	0	0	0.01	0	0.12	0
CPUE Salmonidae	Mean	0.46	0	0	0.4	0.04	0.01	0.54	0.04	1.56	0.03
	Min	0	0	0	0	0	0	0	0	0	0
	Max	21.08	0	0	5.21	1.41	0.23	6.23	0.26	21.08	0.25
	Std Dev	1.62	0	0	0.88	0.19	0.04	1.2	0.1	3.46	0.08
	Variance	2.62	0	0	0.77	0.04	0	1.44	0.01	11.97	0.01
CPUE Umbridae	Mean	0	0.01	0	0.01	0	0	0	0	0	0
	Min	0	0	0	0	0	0	0	0	0	0
	Max	0.35	0.28	0	0.35	0	0	0	0	0	0
	Std Dev	0.03	0.06	0	0.04	0	0	0	0	0	0
	Variance	0	0	0	0	0	0	0	0	0	0

A4 - Trends and p Values for Temporal Data Analysis

	Jurisdiction	Etobicoke	Mimico	Humber	Don	Highland	Rouge	Petticoat	Duffins	Carruthers
Native Species Richness	0.4542	0.8644	0.5864 ↑	0.7906	0.6124	0.2565	0.7836	0.6303	0.2098	0.1639 ↑
Species Richness Ratio	0.4616	0.9271	0.4709	0.8625	0.5352	0.3423	0.8221	0.4313	0.228	0.576 ↑
CPUE	0.0006 ↑	0.6174 ↑	0.3651	0.5435 ↑	0.0912 ↑	0.0439 ↑	0.12 ↑	0.2041 ↓	0.2687	0.5866
BPUE	0.0009 ↑	0.4274 ↓	0.5616	0.7978 ↑	0.1267 ↑	0.3055 ↑	0.0029 ↑	0.2041 ↓	0.2963 ↑	0.1767 ↑
Coldwater	0.2302			0.4765	0.9381	0.3889	0.3813	0.2865	0.0022 ↑	0.3679
Coolwater	0.0003 ↑	0.7107	0.9243	0.2902 ↑	0.0572 ↑	0.1415 ↑	0.0061 ↑	0.2041	0.3896	0.3932
Warmwater	0.356 ↑	0.8921	0.3651 ↑	0.1109 ↑	0.756	0.4354	0.3455	0.5073	0.5192	0.7307
Native	0.0002 ↑	0.6737	0.3651	0.4302 ↑	0.0582 ↑	0.0349 ↑	0.0042 ↑	0.2041	0.2699	0.5866
Non-Native	0.3523	0.0447 ↑		0.9322 ↑			0.6081	0.5134		
Invasive	0.1659 ↑	0.34 ↑	0.3491 ↑	0.5794 ↑	0.9997	0.6919 ↓	0.1028	0.2865	0.7876 ↑	
Stocked	0.2642			0.966	0.6085	0.3889	0.2903	0.2865	0.1438 ↑	0.3679
Benthic Herbivore	0.7375	0.0447 ↑		0.8549			0.6081	0.5134		
Benthic Insectivore	0.0019 ↑	0.4867	0.5258	0.2023 ↑	0.3448 ↑	0.9663	0.0028 ↑	0.7047 ↑	0.5576	0.3012 ↑
Benthic Invertivore	0.0157 ↑	0.354 ↑	0.4966 ↑	0.3309 ↑					0.3679 ↑	
Carnivore	0.6224	0.6672	0.7967	0.8854	0.8509	0.5762	0.7167	0.2865	0.0241 ↑	0.2807
Generalist	0.0167 ↑	0.8513	0.3	0.1921 ↑	0.0442 ↑	0.0321 ↑	0.2504	0.3679	0.2652	0.5584
Non-parasitic Filterer	0.5797			0.9416	0.9982		0.2973		0.1476	
Parasitic Filterer	0.0082 ↓						0.0791 ↓		0.131 ↓	
Water Column Insectivore	0.4396	0.0919 ↑	0.4933	0.7591	0.3938	0.7308	0.0431 ↑	0.9083	0.511	0.3679
Catostomidae	0.3114	0.876	0.6269	0.3311	0.4521	0.8373	0.1218	0.5547	0.1009	0.1199
Centrarchidae	0.2373	0.6388	0.8473	0.3387	0.8628	0.7104	0.0132 ↓		0.7203	0.1825 ↑
Cottidae	0.3962			0.6984	0.9927		0.761		0.2907	
Cyprinidae	0.0018 ↑	0.6361	0.0394 ↑	0.3205 ↑	0.0624 ↑	0.0741 ↑	0.082 ↑	0.2041	0.5136	0.8082
Esocidae	0.3566									0.3679
Gasterpsteidae	0.9856	0.1929	0.7967	0.2337	0.3938	0.7308	0.226	0.9083	0.6116	0.3679
Gobiidae	0.0157 ↑	0.354 ↑	0.4966 ↑	0.3309 ↑					0.3679 ↑	
Ictaluridae	0.541	0.3193	0.2517	0.1239		0.3247	0.7197		0.4249	
Percidae	0.0748 ↑	0.5056 ↑		0.2015 ↑	0.9992	0.3889	0.0396 ↑	0.7382	0.3587	0.4238 ↑
Petromyzontidae	0.6704			0.7658	0.9982		0.7287		0.8199	
Salmonidae	0.4929			0.4788	0.6085	0.3889	0.4567	0.2865	0.0073 ↑	0.3679
Umbridae	0.8484	0.6102		0.374						

Numbers indicate the p value. Arrows represent direction of trends observed in mean. Red values represent statistically significant trends (p<0.05