Land-Use Change and Aquatic Macroinvertebrate Community Structure in the McIntosh Run, Nova Scotia Canada

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1.0 Introduction

Land-cover refers to the physical and biological cover of a land's surface; including water, vegetation, soil, and/or artificial structures (Ellis 2011). This differs from land-use, which is a more complicated term that natural scientists refer to as syndromes of human activities. Such activities include agriculture, forestry, and urbanization that ultimately alter an area's biogeochemistry, hydrology, and biodiversity (Ellis 2011). With these in mind, land-use or land-cover change can then be defined as a human modification of the Earth's surface.

Humans have been modifying the Earth's surface for thousands of years for food and other essentials; however, the current rate, intensity and extent of these changes are impacting ecosystems and environmental processes at local, regional and global scales. Many of today's greatest environmental concerns, including climate change, biodiversity loss, and water, soil, and air pollution, are rooted in these land-use changes. In particular, past research has shown that land-use changes can have significant effects on habitat quality in streams (Graynoth 1979, Lemly 1982, Riley et al. 2003). These changes are mainly a result of vegetation removal that leaves soils vulnerable to mass erosion by wind and water that can lead to significant inputs of phosphorus, nitrogen, and sediments into aquatic ecosystems, causing a variety of negative impacts (increased sedimentation, turbidity, eutrophication and coastal hypoxia).

1.1 Riparian Influence

A riparian buffer is a vegetated area next to a water resource that serves to protect the water from nonpoint source pollution at the same time as providing bank stability and an aquatic and wildlife habitat. A pristine watershed, characterized by historically forested riparian vegetation, has a filtering capacity that protects the associated river from many forms of pollution including nutrient loading and sedimentation (Dillaha et al. 1989, Hill et al. 2004). The pollutant filtering success of a riparian buffer is determined by its position in the landscape relative to the stream as well as its geomorphologic, hydrologic, and biologic processes, i.e. gradient of surrounding uplands, surface flows, as well as vegetation and microbial activity (Naiman et al. 2005). However, due to increased anthropogenic influences such as urbanization and agricultural development there are few “pristine” watersheds left; thus, “minimally impaired” or intact is a more appropriate term when referring to a watershed with high biological integrity as defined by Gibson et al. (1996).

Vegetation removals and especially the removal of large trees in the riparian zones have been linked to a reduction in the riparian buffer’s ability to filter harmful pollutants (Gregory et al. 1991, Naiman and Anderson 1996). Such riparian zone vegetation removals result in increased sedimentation rates and an increase in nutrient runoff (diffuse nitrogen and phosphorus) into the stream at the same time as decreasing the quantity of in-stream Large Woody Debris (LWD) (Gregory et al. 1991, Naiman and Anderson 1996, Haycock et al. 1997).

It is well accepted that land-use change is a leading cause in habitat loss and fragmentation for aquatic systems because of the aquatic ecosystems’ intimate link to the type of land-use found in the associated buffer. This often results in direct and indirect in-stream biotic stresses (Niyogi et al. 2007(2), Naiman and Bibly 1998, Sponseller et al 2001, Naiman et al. 2005).

1.2 Urban Influence

As mentioned above urbanization is a land-use change that modifies both the physical and biotic environment (Platt 2006), which often results in the reduced buffering capability of the riparian zone. Impermeable surfaces, such as pavement or asphalt, which are characteristic of urban areas, decrease the water’s ability to infiltrate the ground. This ultimately affects the stream’s hydrology by increasing peak runoff into the stream and altering the sedimentation levels, nutrient delivery, and down-stream flow velocity. Road-based contaminants, such as hydrocarbons, may also be introduced into the system

(Richards et al. 1993). These urbanized land-use disturbances have been found to alter the stream's benthic macroinvertebrate communities through indirect changes in the stream channel (Naiman and Bibly 1998) such as decreased habitat quality from increased fine sediment, and/or direct influences such as changes in food sources (Dudley et al. 1986, Townsend and Riley 1999).

Sedimentation has been found to have a significant relationship to in-stream health. In-stream health can be defined as ecological diversity, resilience, and the ability to support higher trophic levels. In Nyogi et al.'s (2007) study that looked at longitudinal changes in biota along four different New Zealand streams and explored the relationship between in-stream health and the degree of the pastoral land-use found in its riparian zones (100m on each bank), found a linear, negative relationship between the streams' health and the areas' percent fine sediment.

Finally, direct influences that change the amount of organic mater (OM) that enters the stream habitat have the ability to impact the entire food chain. For example, salmon health depends on a balance between water clarity and turbidity caused by suspended organic particles necessary to sustain their prey (Madej 2004), suggesting if there are no organic particles to sustain their prey there would be no salmon.

1.3 Bio-monitoring

Macroinvertebrate communities are especially sensitive to the riparian vegetation cover and the stream's ability to incorporate OM into the water because many of the invertebrates depend on this OM for food and/or habitat (Vannote et al 1980, Naiman et al 1987, Naiman and Anderson 1996). For example, some macroinvertebrate populations readily colonize LWD to use as a stable substratum and sometimes as a dominant food source; therefore, factors that alter this input of LWD from the riparian zone (i.e. logging) have strong indirect effects on the community (Anderson and Sedell 1979). There are also macroinvertebrate species that are sensitive to fine sediment cover on the stream floor as this can reduce habitat complexity by filling in the interstitial spaces (Lenat et al. 1979, Lemly 1982). These interstitial dwelling species would then be replaced by burrowing taxa that prefer silt habitats, making it more difficult for the higher trophic levels to spot their prey (Lenat et al. 1979, Lemly 1982).

Because of this sensitivity to the land-use many studies assessing impacts of land-use change on aquatic systems have used macroinvertebrates as indicators of in-stream health (Niyogi et al. 2007(1), Niyogi et al. 2007(2), Vannote et al. 1980, Sponseller et al. 2001). This is a technique that uses living organisms to test the land-use impact on the receiving waters in terms of water quality and is often referred to as a bio-indicating or -monitoring. Bio-indicators' act as surrogates of long-term ecosystem health to allow the people monitoring to see the effects of a change opposed to traditional periodic chemical and physical water sampling methods that only records the "snap-shot" status (Environment Canada 2010, David and Simon 1995).

Bio-monitoring using macroinvertebrates has become a commonly used method for community-based monitoring projects because it is a fairly simple and cheap way to identify and collect data on habitat suitability. In particular, aquatic insects' are the most ubiquitous and diverse group of freshwater benthic invertebrates. Their sensitivity to water quality has also been well documented, allowing them to offer a spectrum of responses to various water quality perturbations (Environment Canada 2010, David and Simon 1995). Davies et al.'s (2010) study in eastern Australia compared an urbanized stream's and an adjacent intact stream's macroinvertebrates and found the urban stream communities had consistently lower family richness levels absent of sensitive species, concluding that the urbanized stream's macroinvertebrate community structures were significantly impaired compared to the stream that flowed through naturally intact forest.

Macroinvertebrates have also been used to reflect the effects that different levels of land-use disturbance has on the in-stream health (Gregory et al. 1987, Merrit and Lawson 1992). For instance, Rundle et al.'s (1993) study looked at 58 streams from three regions in the Himalayas to see how the macroinvertebrate structure was related to the dominant land-use (terraced agriculture, forest, or scrub) in each area. They found a significant difference in community structure in the terraced agriculture regions compared to the scrub or forested land-use regions. However this result was said to potentially be confounded by the strong relationship between the land-use type, the altitude and the chemistry of the area.

1.4 Study Justification

The primary objective of this study was to examine in-stream macroinvertebrate assemblages in areas of intact riparian buffers and compare them to areas of urbanized riparian land-use, the results from which could be used to determine, with quantitative evidence, if stricter or more regulated riparian land-use around a stream yields higher levels of biological integrity. This information may then be relayed to active river protection groups and government representatives to raise environmental awareness and habitat protection. To achieve this objective, in-stream macroinvertebrates were sampled over a three-week period from six sites in the McIntosh Run that flows from an up-stream urban core into a down-stream intact forest. Based on aerial photography and groundtruthing it is assumed that the only input of urban influence comes from the up-stream urban core and not from anywhere else. So any down-stream decrease in stream health will be attributed to the up-stream urban source.

Storey and Cowley (1997) and Sponseller et al. (2001) had similar investigations that looked at the up-stream influence on down-stream community structure. Storey and Cowley's (1997) study looked at this juxtaposition in three New Zealand streams to measure the in-stream health recovery after a river passed through an up-stream pastoral riparian land-use and into an intact forested riparian area. They also investigated over what distance this occurred. Storey and Cowley (1997) found an altered invertebrate community structure adjacent to and up to 600 m down-stream from the agricultural land-use, but after this the community structure recovered to a ‘control’ community structure, unaffected by the up-stream agricultural activities. Sponseller et al.’s (2001) study in south-western Virginia, also found one of their sites that had an up-stream intact riparian corridor gave the down-stream urban sites’ invertebrate communities the diversity and general appearance of an intact area, meaning that the down-stream disturbed sites were more similar to up-stream forested sites than disturbed sites that were up-stream of the intact forest sites.

Knowledge gaps in past studies provide the outline for this paper’s research questions and study location. For instance, in Sponseller et al.’s (2001) study, their collection sites were in areas of different topographic and geologic materials and comparisons were made among sites in different catchments. These variables make it difficult to account for all the potentially confounding results that can come from varying altitude and the geological chemistry of the material. These same limitations were said to be confounding in Rundle et al.’s (1993) study that looked at sites in the Himalayas. Potential spatially confounding results may also be present in Davies et al. (2010) study that compared a separate urbanized stream to an adjacent intact stream in eastern Australia. Finally, Storey and Cowley (1997) looked at up-stream land-use influence on down-stream in-stream biotic effects; however, they did not incorporate an up-stream urbanized disturbance and how that impacts an intact down-stream macroinvertebrate community structure.

Urban impacts on in-stream dynamics is worth exploring to be able to provide evidence that urbanized riparian zones affect a stream’s water quality as indicated by a decrease in the benthic macroinvertebrate community structure’s integrity. The McIntosh Run Watershed Association (MRWA) has expressed interest in working with Dalhousie University to increase the river’s database regarding the effects of urbanization on in-stream habitat quality. Furthermore, the McIntosh Run is habitat to rainbow trout, salmon, ducks, and endangered plants as well as providing great visual aesthetics and recreational potential (MRWA 2011); therefore the results of this study may support the protection of this river and its riparian zone from urbanization as it has ecological, social, and economic benefits for Nova Scotia.

This study aims to answer the following research questions:

(1) Do forested and urbanized land-uses in the McIntosh Run's riparian buffer influence different macroinvertebrate community structures as indicated by differences in the abundance of sensitive species? It was expected that urban influenced reaches would yield lower sensitive species abundances relative to the reaches influenced by intact forested riparian zones.

and (2) Are the down-stream macroinvertebrates, in the intact riparian buffer, influenced by the up-stream urban riparian land-use as determined by a gradual change from tolerant to sensitive species with increasing distance from the urban area? It was expected that an increasing distance from the urban influence would show a gradual increase in relative sensitive species abundance.

It was hypothesized that the bio-monitoring with macroinvertebrate communities would reflect the urbanized riparian land-use as urban associated water quality depletion (lower sensitive species abundances) and reduced habitat complexity/suitability (reduced sediment size). The spatial scope of the study was limited to the McIntosh Run and its riparian buffers; temporally the study was limited to the life cycle of the invertebrates captured at the sites during a three-week collection and analysis.

2.0 Methodology

2.1 Site Identification

The initial method for the site selection used satellite map imagery from which groundtruthing was employed to ensure the sites from the maps were accessible and fit the urban or intact riparian classification. To be classified as an urban site there had to be a 50-100% urbanized disturbance, such as paved roads, residential, and/or commercial properties within the 30 m riparian area adjacent to the reach. And to be classified as intact, areas had to have a 30 m+ riparian buffer of intact vegetation (90-100%) including, large trees, fallen trees, and understory coverage similar to what is found in a natural Acadian forested system. After the groundtruthing six sites were established, three urban sites and three intact sites (Figure 2).

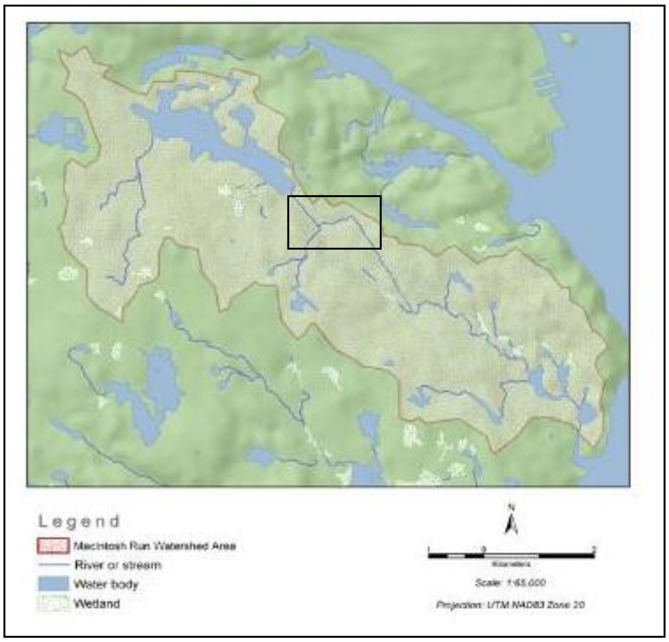

Figure 1. McIntosh Run Watershed. (MRWA 2011) The box represents the site map in Figure 2.

A 30 m riparian buffer was based on information provided by Sponseller et al. (2001) who looked at the land-use changes in south-western Virginia catchments and how that influenced the in-stream physio-chemical features and macroinvertebrate assemblage structure. They examined the relationship between land-cover and in-stream variables at multiple spatial scales and found that local 30 m riparian land-use had the greatest influence on community structure. Nerbonne and Vendracek (2001) found similar results using an analysis of covariance (buffer width and stream as the covariates) and found in Minnesota, USA, in-stream physical habitat characteristics differed across riparian buffering types (grass, grazed, or wooded buffer) not upland land-use types.

All sample sites were limited to the McIntosh Run, Halifax, NS. The geology of the entire 37 square kilometer watershed area (Figure 1; MRWA 2001) is in the Meguma group (White and Goodwin 2011). Every sample site was in the South Mountain Batholith formation (White and Goodwin 2011) therefore it was assumed that any potential geochemical effect would impact all sites equally and any variation in surficial material would be a result of the type of land-use on its surface.

The first intact site (INT01) was just up-stream from Roach's Pond, the second (INT02) was accessed from McIntosh Run Road approximately 273 m up-stream from INT01 and the final intact site (INT03), also accessed from McIntosh Run Road, was 364 m up-stream from INT02 (Figure 2). All three sites had a 30 m+ intact Acadian forest characterizing both banks, however INT03 had a 2 m footpath that cut through the forest 6m from the stream.

Figure 2. Sample site map contains both the urban sites (URB) and intact sites (INT) along the McIntosh Run. Image is from Google Earth (2012).

The first urban site (URB01) was roughly 737 m up-stream from INT03 off Granby Crescent, adjacent to residential back yards on its right bank and a frequented footpath on its left (Figure 2). The second urban site (URB02) was approximately 530 m up-stream from URB01 by the Herring Cove Road bridge adjacent to the “Royal Flush” parking lot that occupied the right bank and a residential area that occupied the left. The final urban site (URB03) was about 370 m up-stream from URB02, located beside the Captain William Spry Community Center parking lot (left bank), a residential neighbourhood (right bank), and just down-stream from a large shopping centre complex’s parking lot and a road bridge coming off Herring Cove Road.

2.2 Study Reach

To standardize the sampled stream-area across all 6 sites the entire reach was first visually estimated by identifying changes in the river morphology, such as a shift from a riffle-pool to a cascade-pool sequence. The Study Reach at each site was then determined as five times the river width (this was approximately 30m for each study site; Environment Canada 2010) and included at least one riffle pool sequence to capture the full range of habitats present for the macroinvertebrates that were inventoried at each site.

2.3 Water Chemistry

Canada’s traditional methods for water quality testing focus on the river system’s chemical and physical properties that are assessed through water sampling and are compared to established water quality guidelines (Environment Canada 2010). However, more recent approaches in assessing river health recognize the importance of examining biological components such as sensitive species whose presence or absence indicates measurable responses to environmental changes (i.e. changes in pollution levels, US EPA 2008) in addition to the traditional sampling methods to allow for monitoring changes regarding invasive species prevalence/presence, habitat degradation, and a stressor's direct effect on existing biota (Environment Canada 2010).

The objective for testing water chemistry was to see if all the sites (urban and intact) had the same values for all the measured parameters (temperature, pH, specific conductivity, and dissolved oxygen). If they did not then the significantly different parameters could be used to provide support for any potential variability in the invertebrate samples that may not link directly to the riparian land-use. For instance, temperature was recorded because it is a key physical variable that directly affects many of the physical, biological, and chemical factors that influence aquatic organisms. It imposes fundamental constraints on animal physiology as some macroinvertebrates prefer narrow ranges in temperature, (stenotherms) where others are able to tolerate broader ranges (eurytherms) (Naiman and Bilby 1998). Thus, predictions could be made if temperatures were significantly different from one another, such that some sites could have different species present because of the difference in the species' range of tolerance. pH was recorded because aquatic organism are known to generally thrive within a small pH range with the greatest diversity of them preferring the pH range 6.5-8.5 (Environment Canada 2010). If the pH left this preferred range the species would be expected to be limited to tolerant species.

Dissolved oxygen (DO), was recorded because it reflects the water's ability to support life. Streams are usually completely saturated with dissolved oxygen, thus oxygen levels rarely limit macroinvertebrate populations (Naiman and Bibly 1998). A healthy river that can support a fish population, and all the trophic levels below, has approximately 9.0ppm DO (Lenntech 2011). Waters with higher concentrations of DO are considered to be able to support many animal types versus the waters with low DO that are occupied by fewer species that are able to tolerate anthropogenic pollutants. Low levels of DO may be caused by warm water (cold water holds more oxygen) or if there are too many bacteria associated with aquatic plant decomposition. Finally, conductivity, a measure of ion concentration in the water, was recorded. The conductivity in streams and rivers is primarily affected by the local geology. Discharges into the stream can change the conductivity depending on the contents. For example, a failing sewage system would raise the conductivity due to the presence of chloride, phosphate, and nitrate; where an oil spill would lower the conductivity. Generally, the conductivity in the United States rivers' range from 50 to 1500 µs/cm (EPA 2011). However, other studies that looked at inland fresh waters' ability to support a good mix of fisheries found a range between 150 and 500 µs/cm (EPA 2011). If the conductivity falls outside this range it may suggest that the water is not suitable for certain species of fish or macroinvertebrates. Therefore any variation in the conductivity among sites would suggest a pollution source is impacting one (or more) site(s) that is not impacting the other sites.

The water quality parameters were measured using a YSI 650 MDS Multi-probe. The YSI was obtained from a local community-based environmental monitoring network at Saint Mary's. The YSI was calibrated for conductivity, pH and dissolved oxygen in the lab at Saint Mary's following the recommended calibration methods provided by the manufacturer. The YSI was also calibrated for dissolved oxygen at each sampling site to take into account any variations in local atmospheric conditions.

2.4 Invertebrate Assemblages

Benthic invertebrates were collected from all sites in a three-week period starting November 09, 2011 because fall collections are believed to give the most accurate representation of the invertebrate community in their adult morphology (Environment Canada 2010). A three-minute kick-net sample was conducted along the estimated 30 m sample area at each site (similar to Environment Canada 2010 and Rundle et al. 1993) and the invertebrates were then analysed in a lab to identify changes in community structure among sites.

1. A kick-net (500µm) was placed down-stream of the collector (kicker) with its flat side resting on the substrate of the stream.

2. Walking in an up-stream direction, the substrate was kicked to disturb a depth of ~5-10 cm at a constant rate (if needed to pause to take a breath the timer was stopped). Large cobbles were turned over and rubbed by the collector's foot to dislodge any macroinvertebrates clinging to the interstitial spaces and the surfaces of large boulders were brushed by hand whilst dragging the net along the bottom of the stream behind the kicker.

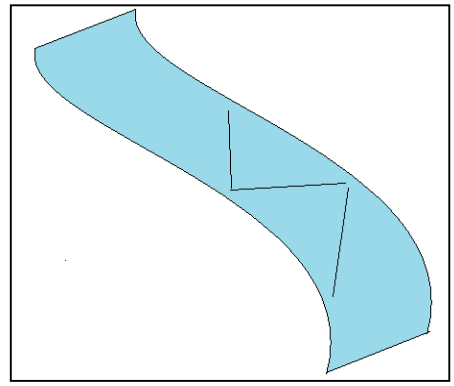

Figure 3. Illustration of the zig-zagging path up the stream from bank to bank with the kick net.

3. The net was always held close to the area that is being disturbed to ensure that most of the disturbed substrate and organisms were swept into the net by the current.

4. A continuous zig-zag pattern was disturbed from bank to bank in an up-stream direction (Figure 3) for a period of 3 minutes (a stop watch was used). The sampling included stream habitats directly adjacent to the stream bank as this region may have contained aquatic macrophytes that support a unique fauna. This way the samples collected invertebrates from all microhabitats in the stream in proportion of their occurrence.

5. The contents were then rinsed from the net into a basin to remove large debris and to transfer the collected invertebrates into a sample jar filled with 80% ethanol (prepared in the lab) to fix the collected individuals.

6. Individuals were then identified to their order in the lab.

2.5 Substrate Characteristics

After the samples were collected the substrate in the sample area was characterised by doing a step-toe procedure pebble count similar to the Wolman Pebble Count (Wolman 1954). This measured the b (or intermediate) axis of every rock (Figure 4) that the sampler's toe touched on every second step (once again zig-zagging through the sample area) for 100 stones (Environment Canada 2010). The substrate characteristics are important to measure because they aid in identifying the hydrological characteristics of a river and the type of habitat that is available to the associated aquatic organisms (Naiman and Bibly 1998).

1. The researcher once again zig-zagged through the sampling area stopping approximately every two steps to lean down and touch the rock that is nearest to their toe without looking.

2. The material that the tip of the finger is touching, being sure not to bias the measurements by recording the largest pebble nearest to the finger rather than the one it is touching, was pulled out and measured along its intermediate (b) axis (Figure 4) in centimetres (this is the diameter perpendicular to the longest axis (a)). If the rock could not be pulled out then the researcher measured the b axis in the water.

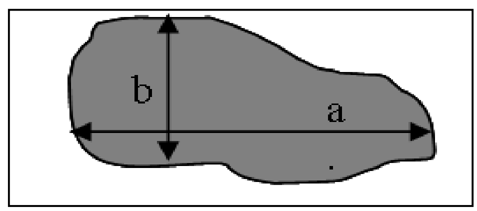

Figure 4. Illustration of the intermediate (b) axis of a rock.

3. For the case of bedrock, fine sediment (particles <0.5 cm), or organic material, B, F or O was recorded in the pebble count table.

2.6 Geomorphology

As it is mentioned above, attempts were made to limit the variables that may influence the macroinvertebrate communities other than the riparian land-uses' influence. To do this the bankfull width, depth, largest stone, and slope were measured and compared across all 6 sites to hopefully conclude that the sample areas, within each reach, have the same river morphology according to Rosgen's river classification system (Rosgen 1996).

1. Bankfull width was measured from the unvegetated gravel bars on either side of the river at the five equally distant sections in each reach.

2. The bankfull depth was measured at the thalwag with reference to the height of the unvegetated gravel bars along a channel cross section in a riffle pool break at the same five equally distant sections in each reach.

3. The largest stones b-axis was measured at each of the five equally distant sections in each reach. When identifying the largest stone there had to be evidence of movement by flowing water during the past decade indicated by its incorporation into the channel bed (other sediment knitted around the larger stones) and not being isolated and distinctly different than all others in the sample area.

4. The five values were averaged for each measurement to give the final value for each sample reach.

5. Finally, slope was measured using the changes in elevation from a GIS map.

2.7 Statistical Analysis

The compositional differences among sites were assessed by quantifying the taxonomic richness of commonly intolerant taxa, *Ephemeroptera*, *Plecoptera*, *Trichoptera* (EPT), widely used in the literature as indicators of disturbance to stream communities (Niyogi et al. 2007(1), Nerbonne and Vondracek 2001, Sponseller et al. 2001). The relative abundance of these sensitive species (%EPT) in each site was used in a comparison of means to see if there was a difference in community structure between the two land-use types. This data was also used to test the importance of up-stream riparian land-use on the aquatic macroinvertebrate community structure in down-stream reaches. By sampling along a potential gradient down-stream from the urban impacted areas the results of this analysis should show if there is a gradual change in the macroinvertebrate community with increasing distance from the urban core (up-stream intact sites have a lower relative abundance of sensitive species than the down-stream intact sites) or if the macroinvertebrate structure is only dependent on the directly associated land-use in the riparian buffer (there is no gradual increase in species abundance with increasing distance from the urban core, but the intact sites are significantly different from the up-stream urban sites).

The data collected from the substrate characteristic measurements was compared across all sites by determining the mean substrate sizes and the percent of fine sediment occupying the area, as this has been found to be a major component that decreases the health of a stream (Nerbonne and Vendracek 2001). This information was then paired with the relative sensitive species abundances at each site to see if there was a relationship between the sediment size and the species composition.

3.0 Results

3.1 Water chemistry

Only the pH differed significantly ($p = 0.021$) from the urban sites to the intact sites (Table 1). However, the pH at all six sites remained below the 6.5-8.5 pH range that characterizes the aquatic organisms' preferred habitat. The rest of the water chemistry parameters remained relatively constant across the six sites ($p > 0.05$; Table 1).

Table 1. The mean Water Chemistry parameters, water temperature (C), pH, specific conductivity (µs/cm), and dissolved oxygen (ppm), for both the urban (URB) and intact (INT) sites. The * represents parameters that differ significantly between the land-use types.

Parameter	**URB**	**INT**	***p*-value**
Water Temp (C)	8.47	6.68	0.286
pH*	5.60	5.90	0.021
DO (ppm)	12.28	12.53	0.665
SC (µs/cm)	181.33	189.33	0.330

3.2 Invertebrate assemblages

One species of *Tubificida* (red thin-worm) lost its colour in the 80% ethanol over time. This resulted in challenges during lab identification and ultimately removed the species from the sample counts. Fortunately a field journal was kept and a note alongside Urban Site 3 (URB03) indicated that there was a minimum of 40 individuals in the sample. Field observations also indicate that none of the missing *Tubificida* species were recovered from the intact sites. Based on this information a count of 40 individuals of *Tubificida* was added to the data for Urban Site 3 keeping in mind that the 40 individuals would contribute to the results' minimum significance. Unfortunately this quantitative result does not reflect the same accuracy as the other species identifications but without this significant addition of intolerant species in the URB03 sample the results would be skewed to misrepresent the observed macroinvertebrate community structure.

Table 2. Total number of individuals by order in both land-use types; urban (URB) and intact (INT). Orders with an * represent sensitive species.

Order	URB	INT
Ephemeroptera*	51	85
Plecoptera*	11	29
Trichoptera*	54	47
Coleptera	6	6
Amphipoda	26	0
Odonata	0	3
Diptera	34	33
Acarina	0	2
Tubificida	90	0

Individuals collected represented nine taxonomic orders across the six sites (Table 2). Seven orders were present in each of the land-use types with *Amphipoda* and *Tubificida* being absent from the intact sites and *Odonata* and *Acarina* being absent from the urban sites. A comparison of means was applied when analyzing the impact that land-use type has on invertebrate community structure and found that the mean EPT species abundance is significantly higher in areas of intact riparian zones versus areas of urbanized riparian zones (one-way ANOVA $F_{1,4} = 17.36$, $p = 0.014$; Figure 5).

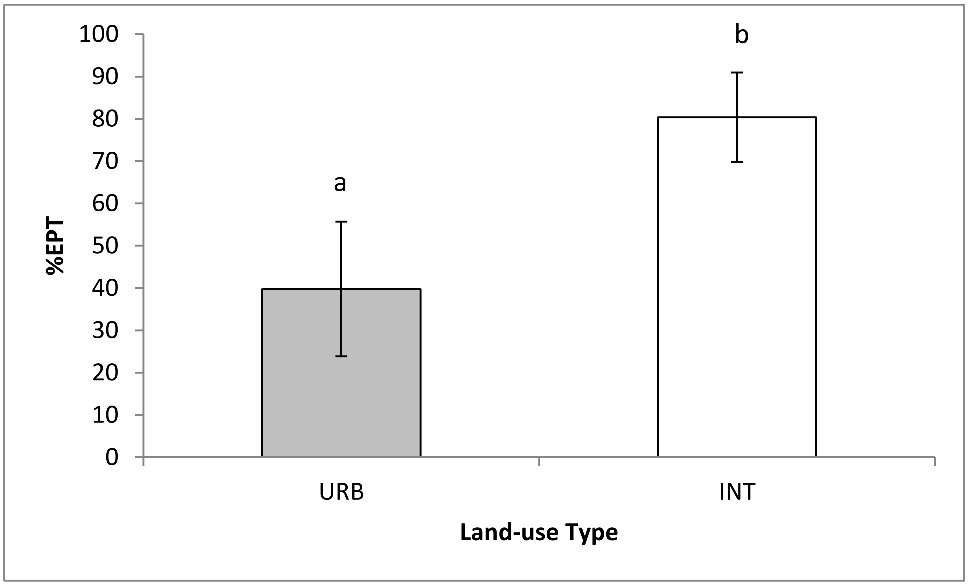

Figure 5. Relative abundance of EPT species (+/- 95% confidence intervals) for the two land-use types; Urban (URB) and Intact (INT), McIntosh Run – Nova Scotia. *Letters (a, b)* represent significantly different means, $p < 0.05$.

3.3 Up-stream influence

Figure 6 shows the relative abundance of EPT species at all sites in relation to their distance from the most up-stream urban site (URB03). The positive trend after there is no longer urbanization in the 30 m buffer (Figure 6: vertical line) suggests an increase in the sensitive species abundance with an increase in distance from the urban pressure.

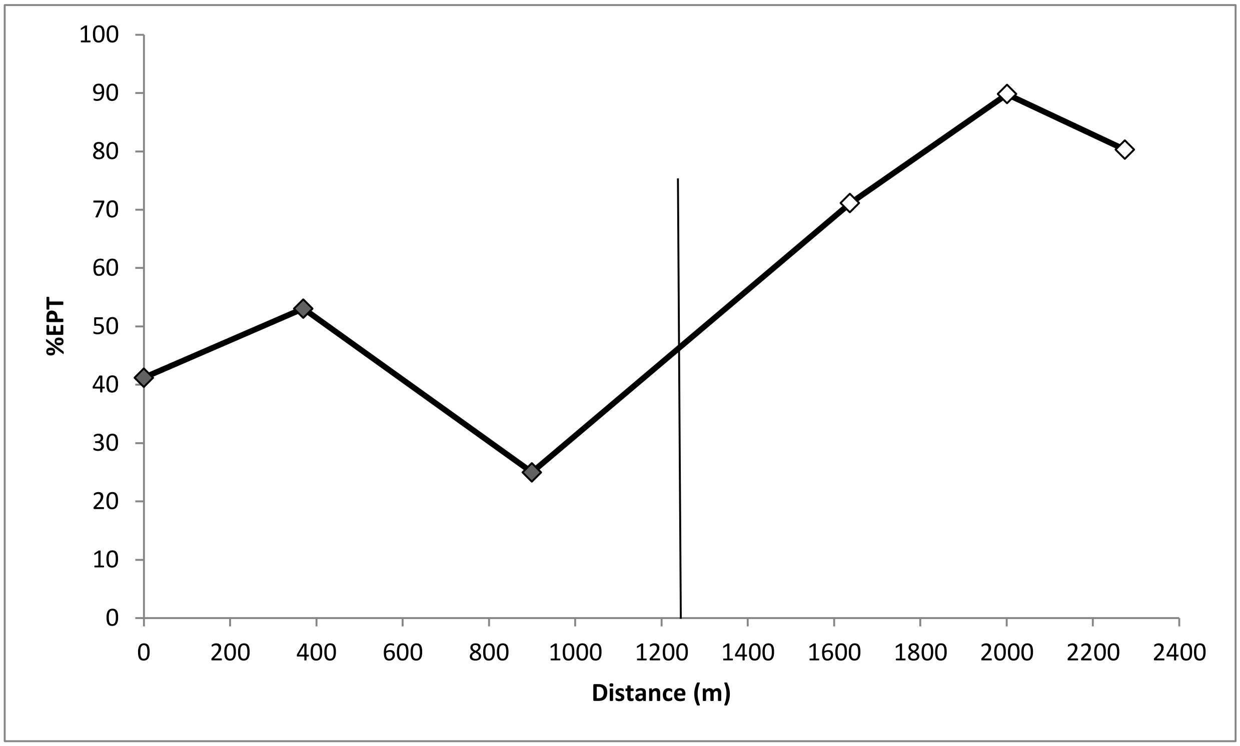

Figure 6. Percent EPT plotted against the distance (m) of the urban sites (grey diamonds) and the intact sites (white diamonds) from the most up-stream urban site (URB03). The vertical line represents the end of the urban influence within the 30 m riparian area (1252 m).

3.4 Substrate characteristics

There was no significant difference of means in the organic matter, fine sediment, or bedrock cover between the urban sites and the intact sites ($p > 0.05$). However there was a significant separation between the land-use types' sediment characteristics when it came to the mean sediment size. The mean sediment size was greater in areas of intact riparian zones versus an urbanized riparian zone (one-way ANOVA $F_{1,4} = 64.45$, $p = 0.001$; Figure 7).

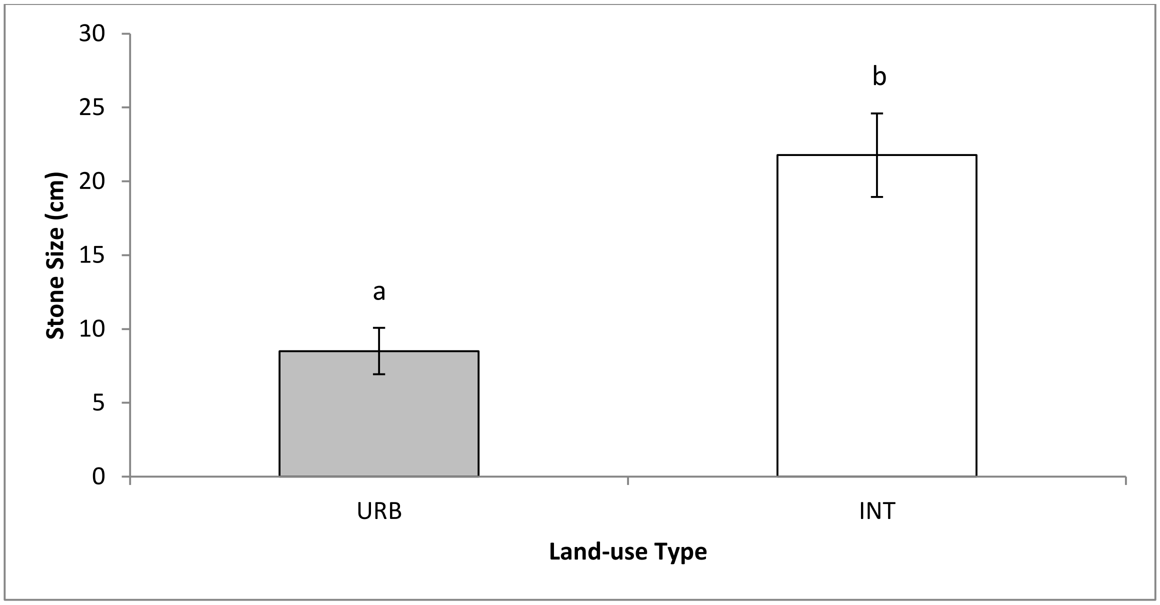

Figure 7. Mean Stone size of rocks > 0.5 cm (+/- 95% confidence intervals) for the two land-use types; Urban (URB) and Intact (INT), McIntosh Run – Nova Scotia. *Letters (a, b)* represent significantly different means, $p < 0.05$.

The greater average sediment size characterizing the benthos in the intact sites resulted in an increase in sensitive species abundance. This is seen in Figure 8, showing the EPT species' abundance positive correlation with sediment size (linear regression $\beta = 2.8879$, $R^2 = 0.7672$, $p = 0.022$).

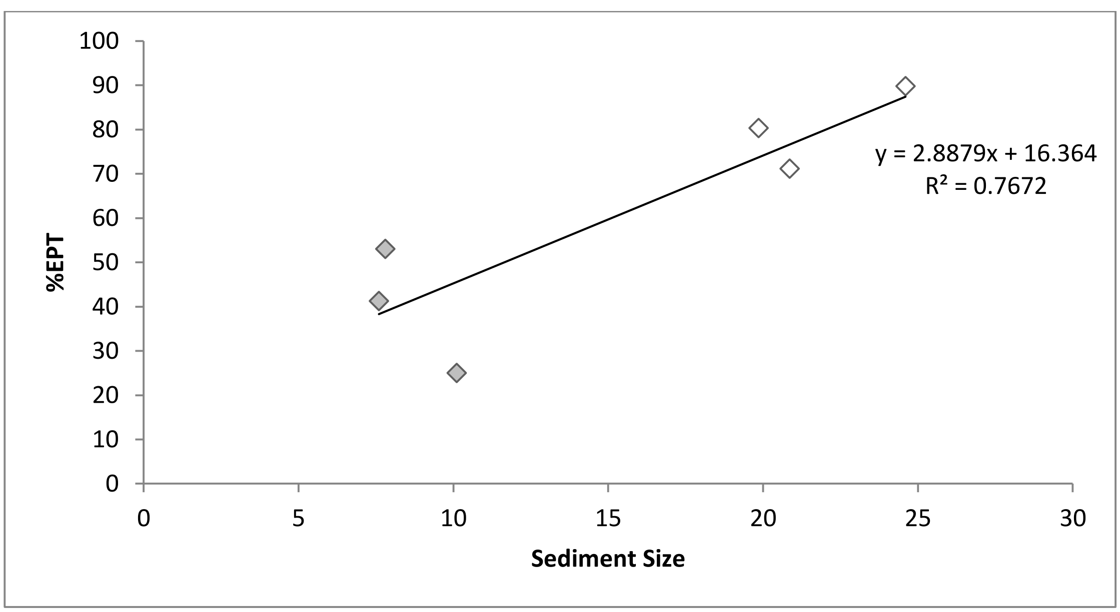

Figure 8. Correlation between relative EPT species abundance and the mean sediment size for each of the six study sites along the McIntosh Run, Nova Scotia; urban sites are represented by the grey diamonds and intact sites are represented by the white diamonds. The solid line represents the predicted mean fit from a linear regression (y = 2.8879x + 16.364).

3.5 Geomorphology

Using the Rosgen broad morphological characterization system the sites were characterized as B2/3/4c stream types (Rosgen 1996). This means that they are single thread channels that have a shallow slope (<0.02) with moderate entrenchment and sinuosity. The variation of the 2-4 accounts for differences in channel material ranging from boulders to gravel. Therefore the McIntosh run would be referred to as a riffle-pool stream (Rosgen 1996).

4.0 Discussion

4.1 Water chemistry

The pH was the only water chemistry parameter that showed a significant difference between sites. It is important to note that the mean pH of the intact and urban locations was 5.9 and 5.6, respectively. These are both below the preferred pH range, 6.5-8.5, which generally supports the greatest diversity of species. These slightly acidic conditions may be attributed to the watershed being in the Nova Scotia region that is impacted by acid rain (Figure 9; ASF 2012) and the difference measured between the intact and urban areas may be because the water chemistry parameters were measured over a three-week period instead of on the same day. The fact that the pH among all the sites was consistently below this preferred range the affect that the acidity has at one location is assumed to impact all the sites and therefore limit the diversity at both the urban and intact sites to the same potential. For instance, EPT species, that generally require neutral habitats (preferred pH range), were found in all six sites suggesting that if their population was being limited by the water’s acidity they would have been limited equally in all sites.

The dissolved oxygen measures across all sites were above the healthy river standard of 9.0 ppm (Lenntech 2011) at 12.28 ppm and 12.53 ppm for the urban and intact sites respectively. This high concentration of DO suggests that the species inhabiting the McIntosh Run are not limited by the water's oxygen content. Finally, the specific conductivity and water temperature were consistent across all the sites suggesting that there were no peaks in ion concentrations or temperature that could influence the community structure of some sites and not the others.

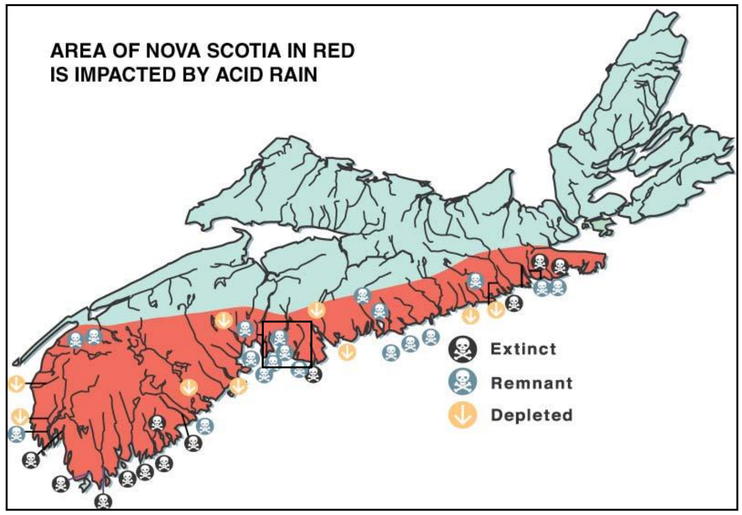

Figure 9. Area of Nova Scotia in red is impacted by acid rain (ASF 2012). The box highlights the location of the McIntosh Run watershed.

4.2 Invertebrate assemblages

The seven orders of species present in the urban sites were Ephemeroptera*, Plecoptera, Trichoptera, Coleptera, Amphipoda, Diptera*, and *Tubificuida*. The *Amphipoda* and *Tubificida* species are the only orders that are present in the urban sites and absent in the intact sites. Crustacea scuds (*Amphipoda*) are found in unpolluted lakes, ponds, streams and springs (Pennak 1989). They required abundant dissolved oxygen and many species only inhabit cold waters with fine sediment. Unlike Annelida aquatic worms (*Tubificids*) that are tolerant of pollution. These aquatic worms feed on detritus, algae, and diatoms in muddy substrate (Pennek 1989). They also have the ability to break down pollutants that settle to the river bottom. Even though both these individuals represent disturbed habitats their presence barely overlaps. For instance, *Amphipoda* species are only found in two of the three urban sites (URB01 and URB02) and of the 26 individuals collected 22 of them came from the first urban site (URB01; 18% fine sediment cover) where the *Tubificida* species were present in all three urban sites but only had 4 individuals in URB01. This suggests there was a shift from pollutant tolerant species up-stream in the urban core (where the *Tubificida* were abundant) to more pollution sensitive species that thrive in fine sediment down-stream in the urban core (where the *Amphipoda* were abundant).

The intact site also had seven orders present; *Ephemeroptera, Plecoptera, Trichoptera, Coleptera, Odonata, Diptera,* and *Acarina*. Similarly there were two orders of species that were not present in the urban sites but present in the intact sites, *Odonata* and *Acarina*. Dragonfly and damselfly nymphs make up the order *Odonata*, and are somewhat tolerant to pollution (NCSU 1976). The three individuals that represent the order were all found in INT03, the closest intact site to the urban core. Therefore, their occurrence may be attributed to this proximity. The second order, *Acarina*, which is only present in the intact sites, has a combined total of two individuals, one from INT01 and one from INT03, both only accounting for one percent of each sample population. Water mites require systems with high oxygen content and are somewhat tolerant to pollution. Their presence may represent a lingering impact of the urban core.

The mean EPT species abundance was found to be higher in areas of intact riparian zones than in urbanized riparian zones. This supports the hypothesis that forested and urbanized land-uses support different community structures, suggesting the in-stream macroinvertebrate community structure is dependent on the type of land-use found in the immediate riparian zone. Because the water chemistry parameters are consistent across all locations the difference in the macroinvertebrate community structures are likely caused by the land-use in terms of urban pollution.

4.3 Up-stream influence

It was hypothesized that if the up-stream urban core influenced the down-stream invertebrate community structure that this would be represented by a gradual increase in in-stream health (increase in sensitive species abundance). To investigate whether or not the up-stream urban core influenced the down-stream intact riparian land-use sites a trend-line was developed. This looked at the relative abundance of sensitive species to the sites' position along the stream. The trend appeared to have a positive relationship with distance, suggesting that there is a decreasing urban influence with increasing distance from the source. Similar up-stream influence was found in Storey and Cowley (1997) and Sponseller et al. (2001) where the down-stream invertebrates still reflected the up-stream land-use. There appears to be rather quick recovery of the sensitive species after the stream runs through the urban core, similar to Storey and Cowley (1997) findings that showed the up-stream influence only reached 600 m down-stream, after which they returned to intact conditions.

4.4 Substrate characteristics

Pollution in the form of fine sediment has frequently been associated with urbanized riparian buffers (Nyogi et al. 2007). This was not the case in the current study's sites, as the percent fine sediment (<0.5cm) did not significantly impact the urban sites more than the intact sites. However there was a significant difference in the average sediment size present at each land-use type. For stones with a b-axis greater than 0.5 cm (less was classified as fine sediment) the difference of means was, on average, 39 cm larger in the intact sites than were measured in the urban sites.

The positive correlation between average sediment size (>0.5 cm) and sensitive species abundance suggests that the larger stones that make up the intact sites' sediment composition favours the presence of sensitive species. This may be attributed to the increase in available habitat likely associated with the increase in sediment size. Similarly Lenat et al.'s (1979) findings suggested a shift from a cobble/gravel habitat to a sand habitat changed the invertebrate assemblages to adaptive (tolerant) species, such as burrowers (*Tubificuida,* and *Amphipoda*).

Field observations showed a clear lack of large woody debris in the urban reaches opposed to the obvious presence of LWD in the intact sites (Vannote et al 1980, Naiman et al 1987, Naiman and Anderson 1996). This would act as an additional habitat supply to invertebrates as well as providing them with a source of OM. These additions are likely accounting for some of the differences in community structure that define the two land-use types (Anderson and Sedell 1979). Finally, with the reduced habitat quality in the form of both reduced sediment size and a lack of LWD, the urban sites are limited to species that can tolerate such conditions and is partially responsible for the differences found in the species compositions.

4.5 Geomorphology

Riffle-pool B2/3/4c streams have a low sensitivity to disturbance and excellent recovery potential (Rosgen 1996). This suggests that the impacts caused by the urban core may have a good chance of recovery with the implementation of better management practices in the riparian zones land-use. Therefore the results of this study may be used to direct policy decisions round buffer zones in Nova Scotia. More specifically the McIntosh Run can increase its ecological integrity by providing more suitable habitat for the rainbow trout, salmon, ducks, and endangered plants at the same time as it increases its already great visual aesthetic and recreational potential (MRWA 2011).

4.6 Future research

Future research projects may expand on this study's result by looking at the recovery of the in-stream communities when a forested buffer is re-established along the length of the stream. Following similar methods, the project will have before and after data that can be used to support the success of best riparian zone management practices. This study's methods could also be used in a five-season study that would be able to account for seasonal variation in community structure. Finally, a long-term monitoring project that looks at the community structure before, during, and after urban development along with more water chemistry parameters (i.e. nutrients) would be able to provide additional support for the importance of an intact riparian buffer. This scope of monitoring would be able to keep an eye out for any further habitat degradation when new developments continue along the river as the HRM is expected to continue growing with an increase in housing demand. Therefore the data from the current study can be used as a baseline for any future changes in the McIntosh Run.

5.0 Conclusion

This study supports the knowledge that riparian land-use influences the in-stream macroinvertebrate communities. The strongest evidence this study found suggests that the directly adjacent riparian areas' land-use has the greatest influence on in-stream community structure even though there was a trend that showed a gradual increase in macroinvertebrate health as the distance from the urban core increased. The substrate size and the presence of LWD differences between the two land-use types supports the literature that says the habitat complexity and OM availability impacts the species present in a reach.

Finally, this projects' information may be relayed to active river protection groups and government representatives to raise environmental awareness and habitat protection of these riparian areas so that during future urban development urban designers will hopefully focus on maintaining the 30 m intact riparian buffer. Also, on-going monitoring of macroinvertebrate assemblages should be conducted in Nova Scotia streams so when/if there are significant decreases in sensitive species abundances action to protect the system can be taken.

6.0 Resources

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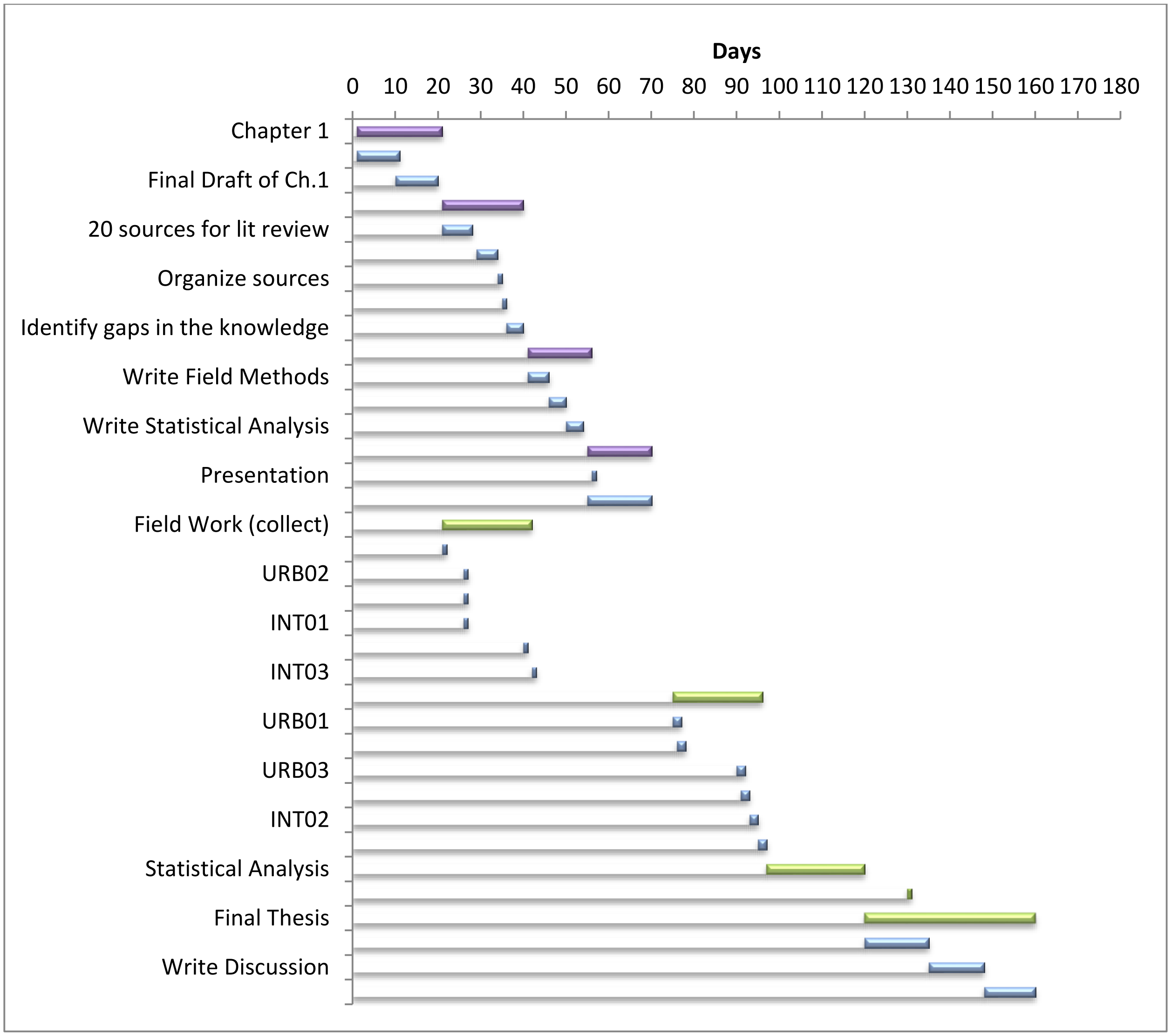
Appendix A Gantt Chart



Appendix B Literature Review Table

Authors	Contribution	Limitations and Gaps
Land-Use		**- This section looks at the connection of in-stream processes to the land-use in the riparian zone and how they affect one another. My study will not focus on gaps in this area of study but instead will use this information to support other areas of my research.**
Naiman et al. 1987	- Decrease in riparian influence with increasing channel width	
Rundle et al. 1993	- Community structure is related to land use	
[2]Niyogi et al. 2007	- Streams are intimately linked to the land-uses in their catchments	
Hill et al. 2004	- "Riparian vegetation can limit the erosion of fine sediments and particulate nutrients into streams, ... take up nutrients directly or enhance microbial uptake, including dinitrofication"	
Wallace et al. 1997, Burton and Likens 1973, Quinn et al. 1997	- Trees hanging over the stream can minimize the solar heating of stream water as well as provide large amounts of organic matter to fuel the stream food webs - Reduced streamside vegetation and a subsequent increase in solar radiation being able to reach the stream channel can increase its temperature.	
Dillaha et al. 1989	- Wider buffers have shown to increase the filtering capacity of sediment	
Peterjohn and Correll 1984	- Intact streamside vegetation inhibits the delivery of sediments to streams	
Sponseller et al. 2001	- In-stream physical variables are closely related to land-cover patterns in the riparian scale (as well as mean stream temp) - Catchment land-use influenced the substratum characteristics	
Disturbed Buffers		**- All of these studies have focused on disturbed buffers as a result of agriculture as were most of the papers I have read showing a significant gap for urbanized disturbances in the riparian buffer. These papers are still useful as the talk about the in-stream effects of reduced riparian vegetation.**
Naiman et al. 1987	- Annual respiration is a large function of the standing stock which is controlled by the riparian zone influence (ex. wood debris) as well as other in-stream hydro/geo components	
Rundle et al. 1993	- Removed Riparia may increase stream temp by decreasing the canopy cover	
Graynoth 1979, Lemly 1982, Riley et al. 2003	- Intensified land use is often associated with increased fine sediment input to streams, increased nutrient levels, higher irradiance and higher organic content in the sediment	
[1]Niyogi et al.	- Found main factors from land use that	

2007	affected streams was nutrients and sediments	
Quinn 2000	- "Streams in agricultural catchments usually show declines in stream health compared with pristine streams"	
- **Sedimentation**		**- This section looks at sedimentation and the effects pertaining to increases in fine sediment. My study will not focus on gaps in this area of study but instead will use this information to support my hypotheses and results.**
Furniss et al. 1991	- Road construction and use increases the delivery of sediment to streams	
Water 1995	- Sedimentation is a principal cause of environmental impairment	
Lenat et al. 1979	- habitat phase shift from a cobble/gravel habitat to a sand habitat = change in the adapted invert assemblages	
Angradi 1999	- If either stream were to become more or less sedimented, then the sediment-tolerant taxa would become relatively more or less abundant.	
Pereira 1989	- Forest clearance may alter the hydrology of the stream catchments, increasing erosion and sedimentation	
Angradi 1999, Lenat et al. 1981, Nerbonne and Vondracek 2001	- Negatively affects many animals through reduced physical habitat, a decrease in food quality, and possible damage to taxa with delicate gills and mouthparts	
Townsend and Riley 1999	- "Sedimentation can affect production and diversity of animals both by direct (i.e., reduced habitat) and indirect pathways (i.e., reduced food from primary production)"	
Nerbonne and Vondracek 2001	- "Riparian Buffers can reduce sedimentation into the streambed via two pathways: reducing channel erosion by increasing streambank stability or by filtering sediment from overland runoff"	
Urban Buffers		**- My study is going to be similar to Sponseller et al. 2001 study that looked at the effects of land-use on benthic macroinvertebrate assemblages in southern Appalachian headwater streams; this paper will provide good background and expectations to my results however my study differs in that I will be looking at an exclusively urban influenced watershed vs. their Urban and agricultural watershed. My study will also look to find a potential gradient**
Platt 2006	Urbanization is a disturbance that modifies its physical and natural environment without completely erasing it	
Waters 1995	- Urbanization dramatically increases the amount of fine sediment delivered to waterways	
Galli 1991	- Increases in in-stream mean temperatures may be from "run-off heated by impervious surfaces in residential areas"	

Sponseller et al. 2001	- "Results suggest that changes induced by local, near-stream development are sufficient to alter community structure, regardless of land-cover patterns found further up-stream"	**away from the urban impacted areas to see if there is a gradual change in the macroinvert community or if the distance isn't a issue and the macroinvert structure is primarily dependent on the adjacent riparian buffer.**
Other variables impacting the stream ecosystem		**- This section is to tell me what variables I need to try and standardize in my study so I can limit potential confounding results. My study will not focus on gaps in this area of study but instead will use this information to support my methods.**
Naiman et al. 1987	- "There were considerable seasonal, site-specific, and regional deviations attributed to the influence of watershed climate and geology, riparian conditions, tributaries, location-specific lithology and geomorphology, and to varying histories of human disturbance." - "The standing stock of carbon in the water column increased down-stream due to an increase in depth, rather than from an increase in carbon concentration."	
Downes et al. 1993	- Found significant spatial variation in water velocities, depths, chlorophyll a, and organic biomass concentrations	
Stream ecosystems		**- My study will not focus on gaps in this area of study but instead will use this information to support my study in the importance of a riparian buffer to the stream ecosystems.**
Pinay et al. 1990	- "Interactive nature of undisturbed stream-floodplain habitats and their potential to efficiently utilize organic matter inputs"	
Merritt and Lawson 1992	- We must consider the stream and floodplain as complementary systems.	
Vannote et al. 1980	- "Streams are envisioned as longitudinally linked systems in which ecosystem-level processes in down-stream reaches are linked to those in up-stream reaches."	
Macroinvertebrates in streams		**- This section looks at macroinvertebrates and their role in the stream. My study will not focus on gaps in this area of study but instead will use this information to support my methods.**
Merritt and Lawson 1992	- Organic material from the floodplain and how it affects the types of macroinvertebrates found in the stream - Functional role of inverts in the stream ecosystem	
Williams and Williams 1993	- Invert migration up-stream is positively correlated with water temperature	
Waters 1995	- "Benthic organisms are considered most likely to be affected by deposited	

	sediment."	
Townsend and Riley 1999	- "Long-term stress will have produced a biota with little resilience to further impact"	
[1]Niyogi et al. 2007	- Species richness may not be highly sensitive to anthro impacts if tolerant species replace the sensitive ones	
[2]Niyogi et al. 2007	- Species richness (# of taxa) didn't change but the types of taxa found did	
Vannote et al. 1980	- "Some changes in macroinvert communities may also be expected because of natural changes in physical characteristics, such as decreasing substrate size, and source of organic matter"	
Quinn et al. 1994	- Thermal regimes are critical of macroinverts life history and ecology	
Sponseller et al. 2001	- Macroiverts tend to have greater diversity with the highest algal biomass and biofilm standing stocks - found that the stream Invert density and production may be positively correlated with algal biomass	
Dudley et al. 1986	- Might influence invert density directly = food source, accumulating other food resources (i.e. detritus, smaller epiphytes) - or indirectly = increasing habitat availability	
- **Why sample in fall?**		**- My study will not focus on gaps in this area of study but instead will use this information to support my methods and scope.**
Peterson and Cummins 1974	Major time period for detritus processing by inverts is in the fall and winter	
Williams and Williams 1993	- (counter arg) Dramatic decrease in benthic densities coincide with increases in the drift that may be indicative of animals being displaced down-stream	
Environment Canada 2010	- The CABIN protocol says that the best time to sample aquatic macroinverts is in the fall because of safe wadeable stream conditions and mature invert life stages (easier to identify)	
Macroinvert Bioindicators		**- This section is used to justify why Macroinverts are used in my study as they are legitimate indicators of stream health. My study will not focus on gaps in this area of study but instead will use**
Williams and Williams 1993	- Many lotic invertebrates have been shown to be temperature dependent	
Pinder 1986	- Chironomid = indicators of sediment effects because of their ubiquity, high	

	abundance, and relatively low mobility in gravel substratum - 2 subfamilies: orthocladiinae = on cobble and gravel; Chironominae = fine sediment and silt with a higher organic matter content (more important)	**this information to guide my statistical analyses and support my results.**
Mattheai et al. 2006	- Sediment addition resulted in reduction of overall invertebrate taxon richness and richness of EPT (increase sediment = decrease EPT richness)	
[1]Niyogi et al. 2007	- "Greater densities and biomass may occur in streams with high nutrients compared to pristine streams but sedimentation has been shown in most cases to decrease the invertebrate density" - Subsidies = increased nutrients; stresses = fine sediment (Subsidy-stress pattern/ threshold response)	
[2]Niyogi et al. 2007	- All invert indexes decreased with increasing fine sediment (%) - "One might expect a decline biotic indices as inverts shift from taxa associated with cobbles (EPT taxa) to taxa associated with fine sediment (oligochaetes and amphipods)"	
Karr 1981	- Bioindicators are advantageous because they incorporate a longer time period than a measure of physical habitat at a fixed point thus capturing critical impacts that standard water testing would miss	
Sponseller et al. 2001	- Chironomids = intolerant taxa	
	- **Expectations**	**- My study will not focus on gaps in this area of study but instead will use this information to support my conclusions.**
Downes et al. 1993, Nerbonne and Vondracek 2001,Lenat et al. 1979	- Species richness will not vary over spatial scales	
Nerbonne and Vondracek 2001	- Sedimentation: "Inverts that scrape algae form hard surfaces are expected to decline. In contrast, inverts that filter food from the water column will increase"	
Lenat et al. 1979, Lemly 1982	- Inverts that live in interstitial spaces will decline with increase fine sediment and be replaces by burrowing taxa that prefer	

	silt habitats	
Sponseller et al. 2001	- "Diversity, evenness and EPT taxa richness were lowest at sites with the highest maximum stream temperature"	
Methods		
Downes et al. 1993	- Neglect of small-scale variation has produced spatially confounded designs (that is why we will zig zag from bank to bank when collecting inverts to avoid missing a microhabitat, CABIN)	
Sponseller et al. 2001	- Invert samples preserved in 80% ethanol, and individuals identified to genus	
Storey and Cowley 1997	- 600m of native riparian buffer between sites	
Kick Net Sampling		
Rundle et al. 1993	2 min (0.9mm mesh)	
Environment Canada 2010	3 min	
Invertebrate Stream Health Indexes		
[1]Niyogi et al. 2007	- EPT density and richness, percent abundance of noninsect taxa	
Nerbonne and Vondracek 2001	- Index of Biological integrity (IBI) - Rapid Bioassessment protocol (RBP)	
Sponseller et al. 2001	Shannon-Weiner Diversity Index - EPT = intolerant taxa	
McIntosh Run		
MRWA 2011	- "Trail surface was raised as needed to avoid chronic spring flooding and large culverts installed to accommodate the runoff from Bridget Avenue" - watershed = 37 square kilometres - length = 12.8 km - Environmental challenges: - Bayers lake - Direct runoff from parking lots (South Centre Mall, Bayers Lake Industral Park) - Stream bank modifications (wetland infilling, de-vegetated) - Developments (residential and commercial) - Pump house overflow - Habitat to rainbow trout, salmon, ducks, and endangered plants	

Management implications		**- This section is to find potential management uses for the data I use. My study will not focus on gaps in this area of study but instead will use this information to support my conclusions in the area.**
Merritt and Lawson 1992	- "The main stream channel therefore is used principally as a route for gaining access to adult feeding areas, nurseries, spawning grounds or as a refuge during low water periods or during the winter"	
Acronyms		
Angradi 1999, Nerbonne and Vondracek 2001	BMPs = Best Management Practices	
Sponseller et al. 2001	EPT = Ephemeroptera + Plecoptera + Trichptera - Widely used as an indicator of disturbance to stream communities	