Credit Valley Conservation

Terrestrial Monitoring Program Report

2005 - 2009

Monitoring Wetland Integrity within the Credit River Watershed
Chapter 3: Wetland Vegetation

CVC
CREDIT VALLEY CONSERVATION

Monitoring Wetland Integrity within the Credit River Watershed

Chapter 3: Wetland Vegetation 2005-2009

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ABSTRACT

Wetland Vegetation in the Credit River Watershed Summary of Monitoring Results 2005-2009
Temporal Trends: Species richness, species diversity and weedy species richness all increased between 2005 and 2009. The proportion of native species and species evenness both appeared to decrease. Many of the remaining parameters fluctuated between years; however, no significant trends were observed and these parameters appear to be relatively stable over the five year monitoring period.
Spatial Trends: Species richness and diversity were not different among the three physiographic zones. The Lower zone contained a lower proportion of native species than the Middle and/or Upper zones and weediness was higher in the Lower zone compared to the Middle and/or Upper zones. There was no difference among the zones for any of the floristic quality parameters or for rare species.
Relationships with Landscape Metrics: A number of vegetation parameters indicative of wetland health were positively correlated with habitat patch size, percent natural cover and matrix quality and negatively correlated with percent urban cover. The number of individuals with a weediness score of -3 and weedy species richness both displayed opposite relationships with landscape metrics. Species richness was not correlated to habitat patch size. All three selected species showed some combination of significant positive relationships with percent urban cover or significant negative relationships with percent natural cover and/or habitat patch size. None of the studied vegetation parameters or selected species displayed a significant relationship with the distance to the nearest road landscape metric.
Recommendations: Trends of changing parameters must be watched closely to determine if intervention will be needed to maintain healthy wetland vegetation communities. Of particular concern is the increase in the number of potentially problematic weedy species, the apparent decrease of the proportion of native species over the five year monitoring period and the low proportion of native species in the Lower watershed.

Wetland vegetation monitoring was conducted as part of the terrestrial component of an overall Integrated Watershed Monitoring Program established at Credit Valley Conservation. Vegetation was surveyed at 18 wetland sites throughout the Credit River Watershed from 2005 to 2009. Monitoring was conducted according to protocols developed by Credit Valley Conservation adapted from Environment Canada's Environmental Monitoring and Assessment Network.

Three hundred and seventeen wetland vegetation species were detected over the four year monitoring period, representing 26% of the vascular plant species known to occur in the watershed. Of these species, 78% were native to Ontario, 55 of which were considered locally rare and 32 of which were considered regionally rare (Kaiser 2001). In addition, 12 of the detected species were considered to be potentially problematic weedy species and are a potential threat to natural areas in the Credit River Watershed.

Species richness, diversity and weedy species richness all increased between 2005 and 2009. However, these increases may be attributed to improved species identification, site knowledge and changes to the monitoring protocol. The proportion of native species appeared to decrease, while the number of problematic weedy species (weediness score = -3) (Oldham et al. 1995) increased between 2005 and 2008. Mean Conservation Coefficient (mCC) and species evenness displayed differences among years, but appeared to be fluctuating rather than increasing or decreasing over time. The remaining parameters remained stable over the monitoring period.

The three physiographic zones in the Credit River Watershed exhibited significant differences for some vegetation parameters. Differences were observed among the Lower watershed and the other physiographic zones. The Middle and Upper watershed were not significantly different for any of the vegetation parameters examined. The Lower zone contained a lower proportion of native species, whereas the Upper and/or Middles zones contained fewer weedy species and problematic weedy species (Weediness Score = -3).

Several of the vegetation parameters including the proportion of native species, native ground vegetation diversity and FQI were significantly positively correlated with some or all of the following landscape metrics: habitat patch size, percent natural cover and matrix quality. Many of the same parameters were also negatively correlated to percent urban cover. The number of individuals with a weediness score of -3 and weedy species richness were significantly negatively correlated with habitat patch size, percent natural cover and matrix quality. Garlic Mustard, Purple Loosestrife and Common Buckthorn all showed some combination of significant positive relationships with percent urban cover or significant negative relationships with percent natural cover and/or habitat patch size. None of the studied vegetation parameters or selected species displayed a significant relationship with the distance to the nearest road.

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1.0 INTRODUCTION

1.1 BACKGROUND

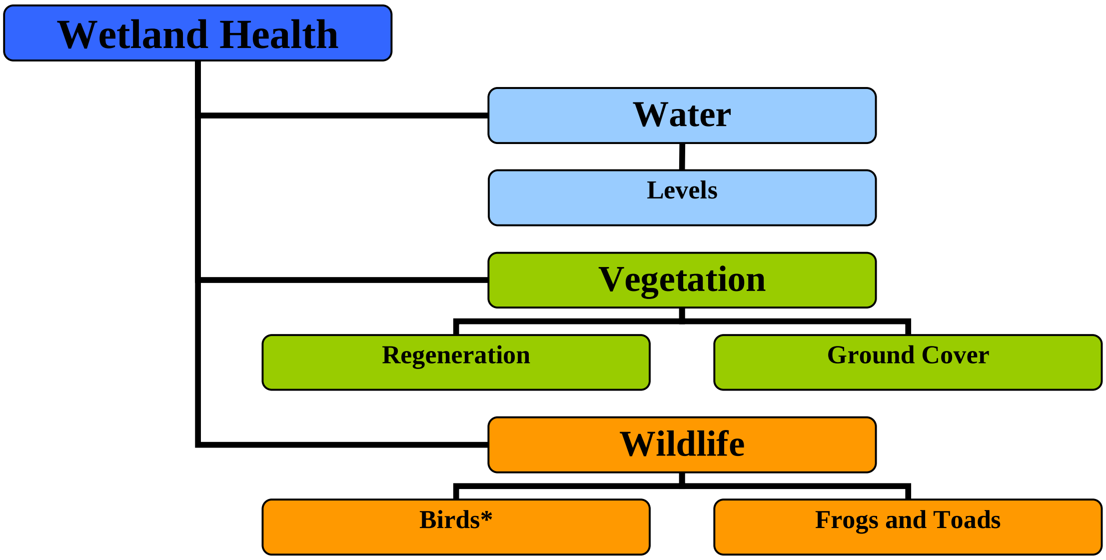
Wetlands provide numerous, irreplaceable hydrological and ecological functions, including stabilization of water supplies, flood abatement, water purification, erosion control, recharging groundwater aquifers and carbon sequestration (Zedler and Kercher 2005; Mitsch and Gosselink 2007). Despite these benefits, wetlands have historically been viewed as unsightly waste areas, and were often drained and filled to accommodate agriculture (Grand River Conservation Authority 2003). Within southern Ontario, approximately 70% of original wetland area is estimated to have been drained for agricultural purposes, increasing to over 80% near major urban centres (Natural Resources Canada 2009).

The types of alterations which lead to wetland degradation can be grouped into four categories, including: a) geomorphic and hydrologic, b) nutrient and contaminant, c) harvest, extinction and invasion, and d) climate change (Brinson and Malvarez 2002; Zedler and Kercher 2005). Current stressors specific to wetlands within the Credit River watershed include habitat removal, nutrient enrichment, organic loading, contaminants (e.g. road salts), sedimentation, turbidity, thermal changes, dehydration, inundation, exotic species, habitat fragmentation, climate change and unsustainable use (e.g. species harvesting) (Dougan and Associates 2009). Within the watershed, the relative impact of each of these processes on wetland health is still unknown. Through monitoring wetlands as part of the Terrestrial Monitoring Program, it is hoped that a deeper insight into the impact of these processes will be gained, to guide future adaptive management and restoration efforts within the Credit River Watershed.

1.2 The Importance of Long-Term Monitoring

There is an increasing demand for better accounting of the condition and health of the environment to determine whether conditions are improving or deteriorating (Niemi and McDonald 2004). An ecological monitoring program increases understanding of the trends and processes of a given ecosystem. A superior monitoring program should address both biotic and abiotic components, as well as function across multiple scales. Monitoring is useful in providing managers with information which can be used for long-term planning, because trends over time can be used to infer future conditions. From an ecological perspective, a monitoring program can also provide insight into cause and effect relationships between environmental stressors and ecosystem responses (Reeves et al. 2004).

In 2002, the Terrestrial Monitoring Program was initiated at Credit Valley Conservation (CVC) to examine the integrity of biotic and abiotic indicators in forest, wetland and riparian ecosystems throughout the watershed. The main goals of the Terrestrial Monitoring Program are to 1) measure indicators of the structure, composition and function of terrestrial ecosystems to assess the ecosystem integrity of the Credit River Watershed, 2) identify status and trends in the integrity of terrestrial communities at the watershed scale and linkages to overall watershed integrity, 3) identify spatial patterns in terrestrial community integrity, and 4) provide meaningful data on which watershed management decisions can be based. Within the watershed several wetland monitoring stations have been established in which soil, vegetation and wildlife parameters are measured to describe wetland conditions in the watershed and to monitor trends over a 25 year period (Fig. 1).



* monitoring began in 2009

Figure 1. Wetland health parameters in the Credit River Watershed.

1.3 Why Monitor Wetland Vegetation?

Vegetation monitoring provides several useful indicators of ecosystem health, including estimates of species richness, species diversity, non-native species richness, community biomass, and community productivity (Geomatics International Inc. 1999). Monitoring herbaceous vegetation provides an early warning system for environmental degradation, including climate change, environmental pollution and land-use change (Roberts-Pichette and Gillespie 1999). Furthermore, monitoring seedling and sapling regeneration provides a measure of vertical structure and allows for understanding of vegetation succession within each community.

Within wetlands, vegetation is known to be a useful indicator of biotic integrity (Simon et al. 2001; Albert and Minc 2004). Plant communities respond to water quality, hydrologic modifications, chemical pollution, and nutrient enrichment (Lopez and Fennessy 2002; Albert and Minc 2004). Submergent species richness is affected by high sediment levels, nutrient enrichment and turbidity, while emergent species also respond to culturally enriched inputs (reviewed in Van Wieren and Zorn 2005). Furthermore, non-native species are characteristic of wetland degradation (Zedler and Kercher 2004). Albert and Minc (2004) suggested that coverage of non-native species is a good measure of wetland condition, as wetlands within heavily urbanized environments tend to be dominated by non-native species.

Monitoring wetland vegetation also allows for early detection of the impacts of climate change. As the climate becomes warmer, it is expected that wetland communities will transition to drier habitat types: marsh, fen and bog communities changing to swamp communities and swamps to non-wetland communities. Wetland vegetation is expected to be highly sensitive to climate change; however, very little is known about the adaptive capacity of these habitats in the face of climate change impacts (reviewed in Dougan and Associates 2009).

1.4 Wetland Vegetation in a Changing Landscape

The Credit River Watershed encompasses 950 square kilometres of land in Southern Ontario, Canada (Credit Valley Conservation 2003). The Credit River flows southeast for nearly 100 km from its headwaters in Orangeville to its drainage point at Lake Ontario. It has been estimated that 33% of wetlands in the watershed have been lost (Dougan and Associates 2009). Most loss has occurred in areas where urban development has been most prominent. The watershed is comprised of 23% natural communities, 11% successional communities, 37% agricultural land use, and 29% urban area (Credit Valley Conservation 2007a).

Though encompassing many unique landscape formations, the Credit River Watershed can be divided into three main physiographic zones based on topography, physiographic regions and subwatershed boundaries (Fig. 2) (Credit Valley Conservation 2007b). The Lower physiographic zone is highly urbanized, containing over 85% of the population of the watershed. The topography of this area is relatively flat with a gentle slope towards Lake Ontario and has been significantly altered by human development. The Lower watershed is comprised of lower permeability sediments, such as silt and clay till, laying on top of Georgian Bay and Queenston shales (Credit Valley Conservation 2007b). The soils in the Lower zone are comprised of clay loams associated with the Peel Plain and the South Slope (Credit Valley Conservation 2007b). These soils have low permeability in relation to the rest of the watershed; however, localized pockets of sand and gravel exist. When compared against government standards (Environment Canada 2004), the amount of both wetland and forest cover in the Lower watershed is classified as poor.

The Middle zone contains the Niagara Escarpment, a landform comprised of steep slopes, rocky outcrops, and thin soil (Credit Valley Conservation 2005); much of this zone is protected under the Greenbelt Plan (OMMAH 2005). The steep topography of this area leads to relatively high runoff volumes and velocities; however, the high forest cover slows runoff and increases infiltration. Soils in this zone are variable as a result of the changing physiography between the Upper and Lower zones (Credit Valley Conservation 2007b). The east portion of this zone is underlain by Queenston Shale, whereas the west portion is underlain by dolomite of the Amabel/Lockport Formation. Surface geology is dominated by silt to clay tills and silty sand to sandy silt, with pockets of ice-contract stratified drift and bedrock or bedrock drift (Credit Valley Conservation 2007b). Due to topographic factors, lower levels of urbanization and protective legislation, the Middle zone contains the greatest proportion of natural cover in the watershed.

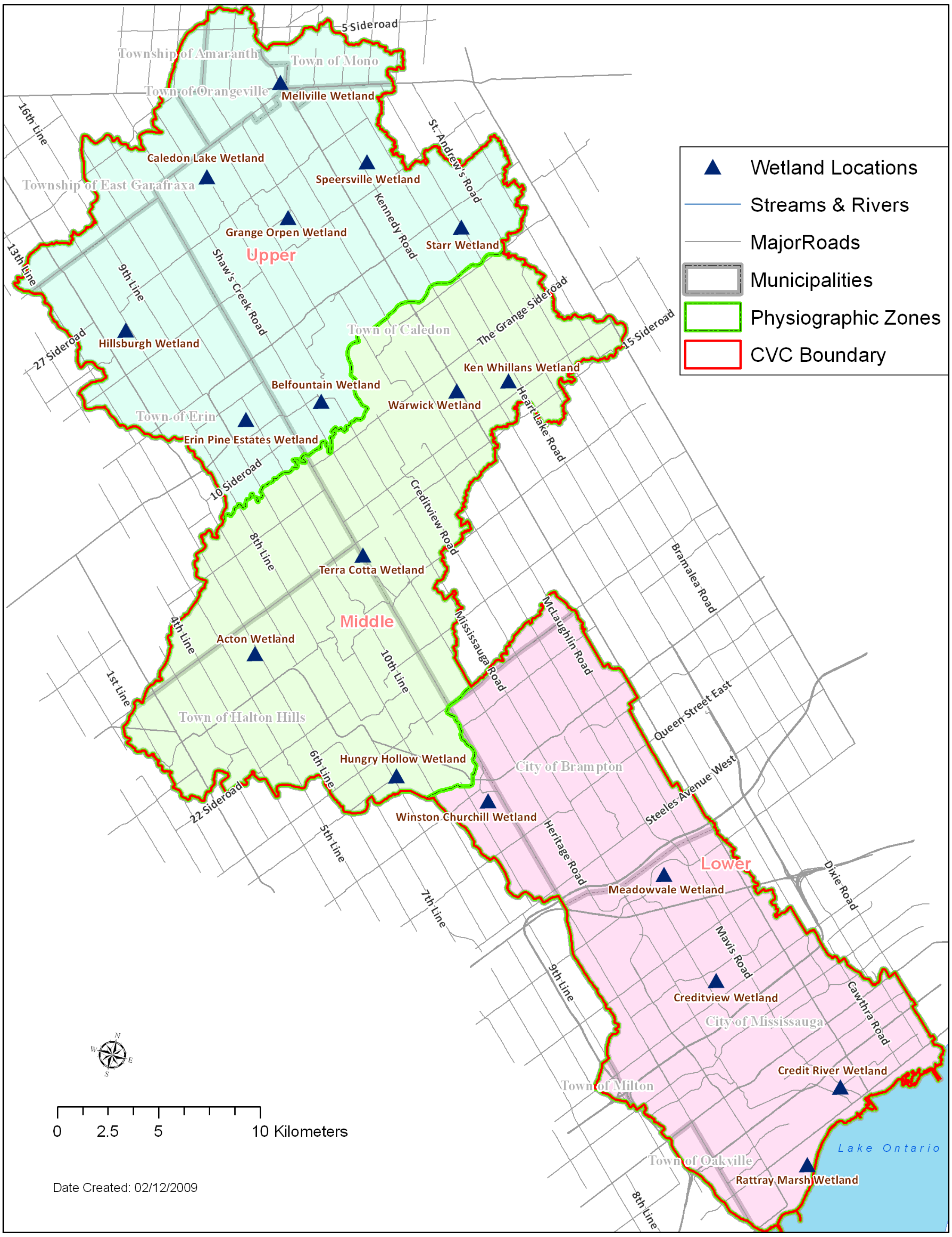


Figure 2. The Credit River Watershed wetland monitoring site locations.

The Upper physiographic zone lies above the escarpment and is characterized by till plains, moraines and glacial spillways (Credit Valley Conservation 2007b). This area is dominated by sandy loam soils that are associated with the Guelph drumlin field and the Hillsburgh Sandhills (Credit Valley Conservation 2007b). The high groundwater recharge rates in the Upper watershed are supported by the relatively high permeability rates of these soils. The Amabel/Lockport Formation is the dominant bedrock type in this area with pockets of the Guelph and Manitoulin dolostones (Credit Valley Conservation 2007b). Surficial geology is dominated by ice-contact stratified drift, silty sand to sandy silt and glaciofluvial gravel. Agricultural land use dominates portions of the Upper watershed, though it also contains several large wetland complexes and numerous headwater streams (Credit Valley Conservation 2007b).

Research in Ontario has demonstrated that the proportion of natural land cover surrounding wetlands increases the diversity of mammals, herptiles, birds and plants (Findlay and Houlahan 1997). In fact, a reduction in wetland area of 50% is expected to result in a loss of 10-16% of wildlife in any taxa group (Findlay and Houlahan 1997). In addition, the development of roads has been shown to alter both groundwater and stream flow (Forman and Alexander 1998), which is in turn expected to have direct impacts on wetland vegetation. Road construction has also been suggested to assist in the spread of non-native species such as Purple Loosestrife (*Lythrum salicaria*) (Forman and Alexander 1998).

Overall, the extent and configuration of natural land cover in the landscape have the ability to alter ecosystem processes, nutrient availability, water availability, and dispersal. These changes can then alter wetland vegetation communities in the watershed. Therefore, observed trends in wetland vegetation will be considered in the context of the changing landscape of the Credit River Watershed.

1.5 Objective: Monitoring Question

Several measures of wetland vegetation are currently being monitored to examine the ecosystem integrity of wetland communities within the Credit River Watershed (Credit Valley Conservation 2010a). This report examines the integrity of the ground vegetation and regeneration layers using a variety of vegetation parameters, including: species richness, evenness and diversity, and measures of floristic quality (mCC, FQI, wetness and weediness). In addition, vegetation parameters were compared to several landscape measures because reliable indicators of ecosystem integrity are expected to be sensitive to anthropogenic disturbance (Noss 1999). Finally, several individual species were examined to determine if their presence was changing over time and to determine if they are sensitive to anthropogenic disturbance. The overall monitoring question being examined in this report is:

ARE INDICATORS OF HEALTHY WETLAND VEGETATION IN THE CREDIT RIVER WATERSHED STABLE?

More specifically, 1) are species richness and diversity differing spatially or temporally through the watershed; 2) does vegetation community similarity differ spatially or temporally through the watershed; 3) are indicators of floristic quality differing spatially or temporally throughout the watershed; 4) do any plant groups differ spatially or temporally throughout the watershed; 5) are there relationships among wetland vegetation and landscape metrics in the watershed; and 6) are there relationships between selected species and landscape metrics in the watershed (Table 1).

Trend analyses were used to examine parameters of interest for increasing or decreasing trends over time, whereas temporal analyses were used to examine if there were differences in parameters among years. Spatial analyses were used to examine whether there was a difference among the three physiographic zones in the Credit River Watershed. Plant groups analyzed include the number of species with high conservatism scores (CC 8-10), the number of locally and regionally rare species, and the number of potentially problematic weedy species (Weediness Score = -3) (see Methods section for details).

Table 1. Wetland vegetation monitoring framework for the Credit River Watershed.

Monitoring Question	Monitoring Variable [a]	Unit of Measurement	Vegetation Layer [b]	Analysis Method
Trend Analyses				
Is species richness changing over time in the Credit River Watershed?	Number of species	Count	Combined vegetation and Ground vegetation	- Linear Regression - Power Analysis
Is total species diversity changing over time in the Credit River Watershed?	Shannon-Weiner Function	Index	Ground vegetation	- Linear Regression - Power Analysis
Is native species diversity changing over time in the Credit River Watershed?	Shannon-Weiner Function	Index	Ground vegetation	- Linear Regression - Power Analysis
Is the mean Coefficient of Conservatism changing over time in the Credit River Watershed?	Mean Coefficient of Conservatism value	Index	Combined vegetation	- Linear Regression - Power Analysis
Is the Floristic Quality Index changing over time in the Credit River Watershed?	FQI	Index	Combined vegetation	- Linear Regression - Power Analysis
Is weedy species richness changing over time in the Credit River Watershed?	Number of species	Count	Combined vegetation	- Linear Regression - Power Analysis
Temporal Analyses				
Did species richness differ among years in the Credit River Watershed?	Number of species	Count	Combined vegetation Ground vegetation, Regeneration	- Repeated Measures ANOVA - Friedman test
Did the proportion of native species differ among years in the Credit River Watershed?	Proportion native species	Proportion	Ground vegetation, Combined vegetation, Regeneration	- Friedman test
Did species diversity differ among years in the Credit River Watershed?	Shannon-Weiner Function	Index	Total ground vegetation, Native ground vegetation, Regeneration	- Repeated Measures ANOVA - Friedman test
Did species evenness differ among years in the Credit River Watershed?	Simpson's Dominance Index	Index	Total ground vegetation, Native ground vegetation, Regeneration	- Friedman test
Did the mean Coefficient of Conservatism differ among years in the Credit River Watershed?	Mean Coefficient of Conservatism value	Index	Combined vegetation	- Repeated Measures ANOVA

Monitoring Question	Monitoring Variable [a]	Unit of Measurement	Vegetation Layer [b]	Analysis Method
Temporal Analyses (Continued)				
Did the number of species with a Conservatism score of 8-10 differ among years in the Credit River Watershed?	Number of species with a Conservatism score of 8-10	Count	Combined vegetation	- Friedman test
Did the mean Floristic Quality Index differ among years in the Credit River Watershed?	FQI	Index	Combined vegetation	- Repeated Measures ANOVA
Did weedy species richness differ among years in the Credit River Watershed?	Number of species	Count	Combined vegetation	- Repeated Measures ANOVA
Did the mean number of species with a weediness score of -3 differ among years in the Credit River Watershed?	Mean number of species with a weediness score of -3	Count	Combined vegetation	- Friedman test
Did the number of locally and regionally rare species differ among years in the Credit River Watershed?	Number of locally and regionally rare species	Count	Combined vegetation	- Friedman test
Spatial Analyses				
Did species richness differ among physiographic zones in the Credit River Watershed?	Number of species	Count	Combined vegetation, Ground vegetation, Regeneration	- Repeated Measures ANOVA - One-way ANOVA - Kruskal-Wallis test - Power Analysis
Did the proportion of native species differ among physiographic zones in the Credit River Watershed?	Proportion native species	Proportion	Ground vegetation, Combined vegetation, Regeneration	- Kruskal-Wallis test
Did species diversity differ among physiographic zones in the Credit River Watershed?	Shannon-Weiner Function	Index	Total ground vegetation, Native ground vegetation, Regeneration	- Repeated Measures ANOVA - Kruskal-Wallis test - Power Analysis
Did species evenness differ among physiographic zones in the Credit River Watershed?	Simpson’s Dominance Index	Index	Total ground vegetation, Native ground vegetation, Regeneration	- Kruskal-Wallis test
Did the mean Coefficient of Conservatism differ among physiographic zones in the Credit River Watershed?	Mean Coefficient of Conservatism value	Index	Combined vegetation	- Repeated Measures ANOVA - Power Analysis

Monitoring Question	Monitoring Variable [a]	Unit of Measurement	Vegetation Layer [b]	Analysis Method
Spatial Analyses (Continued)				
Did the number of species with a Conservatism score of 8-10 differ among physiographic zones in the Credit River Watershed?	Number of species with a Conservatism score of 8-10	Count	Combined vegetation	- Kruskal-Wallis test
Did the Floristic Quality Index differ among physiographic zones in the Credit River Watershed?	FQI	Index	Combined vegetation	- Repeated Measures ANOVA - One-way ANOVA - Power Analysis
Did the number of locally and regionally rare species differ among physiographic zones in the Credit River Watershed?	Number of locally and regionally rare species	Count	Combined vegetation	- Kruskal-Wallis test
Did weedy species richness differ among physiographic zones in the Credit River Watershed?	Number of species	Count	Combined vegetation	- Repeated Measures ANOVA - Power Analysis
Did the mean number of species with a weediness score of -3 differ among physiographic zones in the Credit River Watershed?	Mean number of species with a weediness score of -3	Count	Combined vegetation	- Kruskal-Wallis test
Species Level Analyses				
Was there a relationship between selected species and landscape metrics in the Credit River Watershed?	Selected species compared to habitat patch size, distance to the nearest road and % urban and natural cover	Presence / Absence	Ground vegetation	- Logistic Regression
Did site occupancy of selected species change over time in the Credit River Watershed?	Proportion of sites occupied by selected species	Proportion	Ground vegetation	- Cochrane-Armitage - Power Analysis
Landscape Analysis				
Were wetland vegetation parameters correlated with landscape metrics in the Credit River Watershed?	All above vegetation parameters compared to habitat patch size, distance to the nearest road, % urban, natural and agriculture cover and matrix quality	Variable	Combined vegetation, Ground vegetation, Regeneration	- Spearman Rank Correlation

[a] All monitoring variables were summarized for each individual site in each year across the monitoring period.
[b] Ground vegetation includes all herbaceous plants, woody vines, and shrubs and trees <16cm. Regeneration includes trees and shrubs ≥ 16cm and < 4cm in diameter at breast height (DBH). Combined vegetation includes data from both the ground vegetation and regeneration layers.

2.0 METHODS

2.1 WETLAND HEALTH MONITORING

Eighteen permanent wetland monitoring sites were established in 2002 throughout the Credit River Watershed. These sites were monitored for changes in vegetation from 2005-2009. The wetland sites represent six swamp and 12 marsh communities (Appendix A). The monitored wetlands represent 11 Provincially Significant Wetlands (PSW's), 11 Environmentally Sensitive Areas (ESA's) and six Life Science Areas of Natural and Scientific Interest (ANSI). Wetland Health in the Credit River Watershed was monitored following modified plot-based methodologies developed by Environment Canada's Environmental Monitoring and Assessment Network (EMAN) and CVC. All vegetation parameters were measured annually or bi-annually at the monitoring sites. Wetland monitoring sites consisted of 12 paired sub-plots spaced ten metres apart, established along a 50 m linear transect, which ran along the wetland's hydrological gradient (from dry to wet) (Fig. 3). At each subplot a 1x1m ground vegetation subplot was nested within a 2x2 m regeneration subplot, which shared the same centre point.

2.1.1 Ground Vegetation

Ground vegetation is acutely sensitive to finer-scale disturbances in microclimate (e.g. soil moisture and temperature), so it is an integral early indicator of changes in wetland health (Geomatics International Inc. 1999; Simon et al. 2001; Albert and Minc 2004). At each 1x1m monitoring subplot, species identification was recorded for all herbaceous vegetation (grasses, sedges, ferns etc.) and trees and shrubs with a height <16cm. Each species was also assigned to one of the following cover classes: <1%, 1-5%, 6-15%, 15-30%, 31-50%, 51-75% and 76-100%. In 2008, methodology was revised for assessing wetland vegetation abundance from "percent cover" classes to the actual percent cover a species occupies in a subplot. This was done to enable better analysis of data as the cover classes were found to be too coarse to yield meaningful statistical results. For analysis, 2008 and 2009 percent cover data were reassigned to the appropriate cover class for consistency in data presentation across all years. Ground vegetation was monitored bi-annually, in spring and late summer, to ensure accurate identification of species and to capture plants blooming at different times throughout the season. Methodology followed standardized EMAN protocol (Roberts-Pichette and Gillespie 1999).

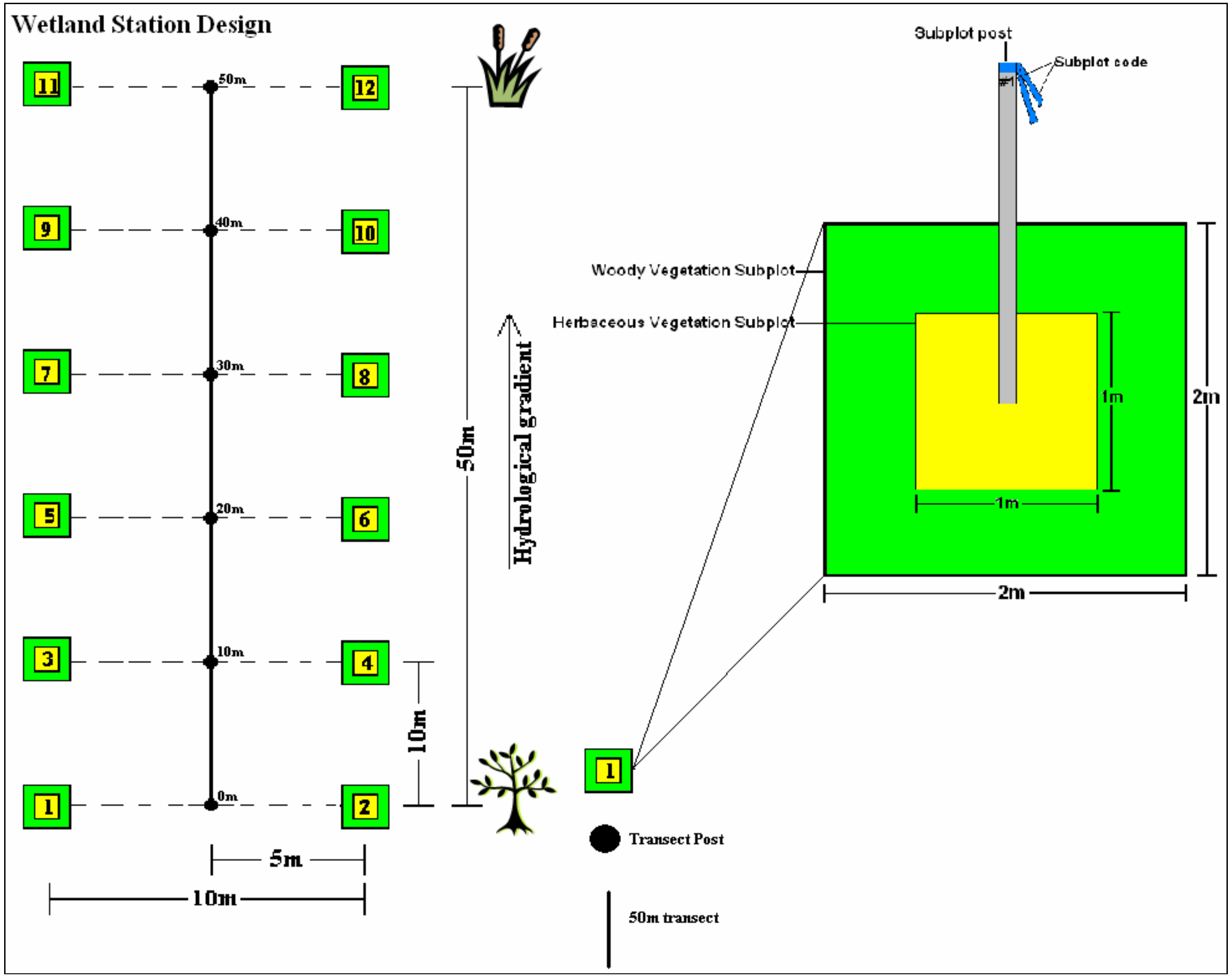


Figure 3. Wetland monitoring site layout.

2.1.2 Regeneration

Regeneration monitoring provides insight into what trees will comprise the future canopy layer of wetlands of the Credit River Watershed. Regeneration was monitored annually in the late summer. Following modified EMAN protocols, tree and shrub stems ≥16cm in height and <4cm Diameter at Breast Height (DBH) originating within each subplot were identified to species and assigned to one of the seven cover classes noted above (Sajan 2000).

2.2 DATA PREPARATION

Although non-vascular plants also provide valuable information about ecosystem health, due to resource constraints and the specialized knowledge required for their identification, only vascular plants were included in analyses. Therefore, any observations of mosses, liverworts and algae were removed from the dataset. All vascular plants identified to species were included in the dataset. Plants identified to genus were included in a grouping if no other plant of that genus was identified to species within the group in question, unless otherwise noted below. These genus-only records were included to provide an accurate representation of the number of species within a site, even if species-level identification was not possible.

Woody species excluded from the regeneration survey included woody vines such as Poison Ivy (*Toxicodendron radicans ssp. negundo*) and woody species that do not have the potential to contribute to the dominant canopy layer in the future, such as Bunchberry (*Cornus canadensis*). A complete list of all woody species not included in the regeneration analyses is presented in Table 2. These species were instead included in those ground vegetation analyses which did not rely on percent cover data.

Table 2. List of woody species removed from the regeneration analyses

Common Name	Scientific Name
Bog Rosemary	*Andromeda polifolia var. glaucophylla*
Bunchberry	*Cornus canadensis*
Climbing Nightshade	*Solanum dulcamara*
Dwarf Red Raspberry	*Rubus pubescens*
Large Cranberry	*Vaccinium macrocarpon*
Poison Ivy	*Toxicodendron radicans ssp. negundo*
Riverbank Grape	*Vitis riparia*
Small Cranberry	*Vaccinium oxycoccos*
Thicket Creeper	*Parthenocissus inserta*
Twinflower	*Linnaea borealis ssp. longiflora*
Virgin's-Bower	*Clematis virginiana*

2.2.1 Vegetation Parameters

Data summaries were conducted for several vegetation parameters listed below. Data was summarized for ground vegetation and regeneration layers separately, as well as for combined vegetation, which incorporates data from both the ground and regeneration layers.

2.2.1.1 Most Common Species: Lists of the most common species in the watershed were developed using only plants identified to species level. The lists were determined by summing the total number of monitoring sites in which each species was observed per year, regardless of the abundance of the species at each site.

2.2.1.2 Species Richness: Richness was calculated by counting the number of unique vegetation species identified watershed-wide and at each site per year. Richness calculations were performed for ground vegetation, regeneration and combined vegetation. In addition, the proportion of native species (ground vegetation, regeneration and combined vegetation) was determined watershed-wide and at each site per year. Proportion of native species was calculated using plants identified to species-level, as:

$$\mathbf{P} = \frac{\mathbf{N}}{\mathbf{T}}$$

Where P = Proportion of native species
N = Number of native species
T = Total number of species (native + non-native).

2.2.1.3 Species Diversity: Vegetation species diversity in the Credit River Watershed was calculated using the Shannon-Wiener Function:

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

Where H' = Index of species diversity
s = Number of species
p_i = Proportion of total sample belonging to ith species determined by percent cover

Diversity values at each monitoring site were calculated separately for each subplot and then averaged to obtain the diversity score for each site. Traditionally, p_i is calculated using the number of individuals of each species. Unfortunately, these data were not available. Instead, cover class was used to determine the proportion of the subplot occupied by each species. To do this, cover classes were first converted to whole numbers by using the mid-point of each cover class (e.g. the 5-10% cover class was converted to 7.5%). The total cover for the subplot was then calculated by summing the cover classes for all detected species. Next, p_i was calculated by dividing the cover class of $species_i$ by the total cover of the subplot. Diversity for each subplot was then calculated using the formula described above. It is important to note that because p_i was calculated using percent cover, opposed to abundance, H' values in this study cannot be compared to other diversity indices for vegetation within the literature.

In a community with only one species $H' = 0$. As H' increases, communities increase in diversity (Krebs 1999). This index was calculated at each site per year. Total diversity was calculated for both ground vegetation and regeneration. However, diversity was not calculated for regeneration in 2009 because of changes in the regeneration sampling protocol which rendered the 2009 incomparable to previous years data. Native diversity was only calculated for ground vegetation, using plants identified to species-level, because of low non-native richness in the regeneration data.

2.2.1.4 Evenness: Species evenness, E, was calculated based on Simpson's dominance index (Simpson 1949):

$$E = (1/\sum_{i=1}^{S} p_i^2)/S$$

where p_i is the proportional cover of species i and S is species richness. Cover class was determined using the same process as for diversity. Evenness is a measure of how evenly the cover within a plot is distributed between species. Evenness values range from 0 to 1. An evenness value of 1 indicates that plant cover within a plot is evenly shared among the species present (e.g. only one species is present, two species both account for 50% of the cover, etc.). A low evenness value indicates that one or a few plants account for the majority of the cover, whereas other plants cover very little of the plot. Regeneration could not be calculated in 2009 for regeneration due to changes in sampling protocol.

2.2.1.5 Floristic Quality Assessment: Plants can reflect the quality or condition of an ecosystem. This relationship between vegetation and site quality was assessed using the Ontario Ministry of Natural Resources Floristic Quality Assessment System for Southern Ontario (Oldham et al. 1995). This system assigned each vegetation species known to occur in southern Ontario several values, including a wetness index, coefficient of conservatism and weediness score. Each index is based on species habitat requirements and these scores were used to calculate several vegetation parameters described below.

Wetness Index

Mean wetness index was calculated for each site using the species specific wetness values listed in the Floristic Quality Assessment System for Southern Ontario (Oldham et al. 1995). Wetness values were assigned to species based on their requirement for wet habitats on a scale of -5 (obligate wetland) to 5 (obligate upland). The mean wetness index was calculated by averaging the wetness scores for each species detected at a given site, per year.

Coefficient of Conservatism

Coefficient of conservatism (CC) scores have been assigned to native vegetation species in the Floristic Quality Assessment System for Southern Ontario (Oldham et al. 1995) and are based on a species tolerance to disturbance and habitat fidelity. These scores were used to calculate three vegetation parameters, including the mean Coefficient of Conservatism (mCC), Floristic Quality Index (FQI) and the number of species with CC values of 8-10 (CC 8-10). Coefficient of Conservatism scores for each species range from 0 (low conservatism) to 10 (high conservatism) and a conservatism value of 8, 9 or 10 indicates that a species is a habitat specialist (OMNR 2008). Mean Coefficient of Conservatism was calculated by averaging the CC scores for each native species detected at a given site. In addition to mCC, the total number of species with a CC value of 8-10 was also calculated for each site. Finally, the Floristic Quality Index was calculated as follows:

$$\mathbf{FQI = mCC} \times \sqrt{\mathbf{N}}$$

where mCC is the mean Coefficient of Conservatism and N is native species richness.

Mean Coefficient of Conservatism and FQI are both measures of the floristic integrity of a given site. Mean Coefficient of Conservatism is solely based on the habitat requirements of detected species, while FQI incorporates species richness into its calculation. Both parameters are useful for examining vegetation integrity, as a site with a high FQI may have a low mCC value and vice versa. For example, a relatively degraded site may have a high FQI value if a large number of disturbance-tolerant native species present (Taft et al. 1997). Given that mCC and FQI have the potential to rank sites differently, it is important to consider both when examining the overall quality of a given location. Mean Coefficient of Conservatism, FQI and CC 8-10 were calculated for each individual site, per year.

Weediness

Weediness was evaluated using the weediness scores provided for non-native species in the Floristic Quality Assessment System for Southern Ontario (Oldham et al. 1995). Weediness scores have been assigned to all non-native species and range from -1 (low impact of the species on natural areas) to -3 (high impact of the species on natural areas). The weedy species richness was calculated for each site by totalling the number of species with a weediness score of either -1, -2 or -3 at a given site. Also, in order to quantify the impact of non-native species that may have serious effects on natural areas in the watershed, the total number of species with a weediness score of -3 (weediness score -3) was calculated. These weediness parameters were calculated for each individual site, per year.

2.2.1.6 Locally and Regionally Rare Species: In order to understand the composition of rare species within the watershed, the number of both locally and regionally rare species was determined using plants identified to species-level watershed-wide and at each site per year. Local and regional rareness designations were based on

Kaiser (2001). The criteria used for determining if a plant was locally or regionally rare were as follows:

- Locally rare - a species that occurred fewer than 10 times in the Region of Peel
- Regionally rare - a species that occurred fewer than 40 times in the Greater Toronto Area (Kaiser 2001).

2.2.1.7 Community Similarity: Vegetation community change was calculated with plants identified to species-level using Jaccard's Similarity Index (Krebs 1999):

$$S_j = \frac{a}{a + b + c}$$

Where S_j = Jaccard's similarity coefficient
a = number of species in year 1 and year 2 (joint occurrences)
b = number of species in year 2 but not in year 1
c = number of species in year 1 but not year 2

Jaccard's Similarity Index is a calculated value used to compare the species similarity between two samples. The index was calculated watershed-wide for the combined vegetation data for 2005 vs. 2006, 2006 vs. 2007, 2007 vs. 2008, 2008 vs. 2009 and 2005 vs. 2009. In addition, Jaccard's Similarity Index was also determined across all years among the physiographic zones, including Lower zone vs. Middle zone, Lower zone vs. Upper zone, and Middle zone vs. Upper zone.

2.2.2 Statistical Analyses

2.2.2.1 Trend and Temporal Analysis: Population trends between 2005 and 2009 were analyzed using linear regression in STATISTICA 7.0 (Statsoft Inc.), with results considered significant when $p<0.05$. Prior to analyses, data were tested for normality and homogeneity of variance using the Shapiro-Wilk test and Levene's test, respectively. If required, data were transformed in order to improve normality and homogeneity (Appendix B). Trend analysis was completed for the vegetation parameters listed in Table 3. Regeneration parameters could not be analysed using linear regression due to a spatial correlation among sites in the regeneration datasets. Trends could not be determined in the proportion of native species and evenness parameters because of the ordinal nature of the data, which necessitated the use of non-parametric tests (McDonald 2009). Weediness score -3, CC 8-10, locally rare and regionally rare parameters were analyzed with non-parametric methods because of the low number of species detected within these groups at each site.

In addition, data were also examined to determine if differences occurred among years. Differences among years were determined with either the parametric repeated measures ANOVA test or the non-parametric Friedman test, depending on the parameter. Although a one-way ANOVA would have been sufficient to test for differences among years, the repeated measures ANOVA was used because this test was already being utilized to determine spatial differences in the data and provided equivalent temporal comparisons to a one-way ANOVA. The Friedman test, a non-parametric equivalent of the repeated measures ANOVA, was used to identify differences among sampling periods (2005-2009) for non-parametric data. In lieu of post-hoc analysis, which is not available for the Freidman test, differences among groups must be inferred through visual examination of the data.

Table 3. Summary of temporal and spatial analyses used to examine vegetation parameters within the Credit River Watershed.

Vegetation Parameters	Parametric Trend Analysis	Parametric Temporal and Spatial Analyses	Non-Parametric Temporal and Spatial Analyses
Ground Vegetation			
Species Richness	X	X	
Species Diversity	X	X	
Species Evenness			X
Proportion of Native Species Richness			X
Native Species Diversity	X	X	
Native Species Evenness			X
Regeneration			
Species Richness			X
Species Diversity			X
Species Evenness			X
Proportion of Native Species Richness			X
Combined Vegetation			
Species Richness	X	X	
Proportion of Native Species Richness			X
Mean Wetness Index [a]	X		
mCC [b]	X	X	
CC 8-10 [b]			X
FQI [b]	X	X	
Weedy Species Richness	X	X	
Weediness Count -3			X
Locally Rare Species			X
Regionally Rare Species			X

[a] Spatial analysis not conducted because start and end points of wetness gradient vary by site.
[b] mCC, Mean Coefficient of Conservatism; CC 8-10; number of species with a Coefficient of Conservatism between 8 and 10; FQI, Floristic Quality Index.

A selected group of wetland vegetation species were also examined for trends using the Cochrane-Armitage test in XLStat (Addinsoft) (Agresti 2002). This test is often used to examine linear trends in binomial proportions of response across increasing levels of dosage in medical studies. In this study, the test has been used to examine if species occurrence was increasing or decreasing over time. Vegetation species chosen for this analysis were selected due to interest in a species distribution and the suitability of its distribution for the required statistical tests. Species were considered for selection if they were of some interest to the program either because they were non-native, uncommon in the watershed or a common native plant. In addition, the species' distribution needed to be appropriate as the statistical analyses would not be meaningful if the species were present at very few or almost all of the sites. Based on the preceding criteria, ground vegetation species examined included: Garlic Mustard (*Alliaria petiolata*), Common Buckthorn (*Rhamnus cathartica*) and Purple Loosestrife.

2.2.2.2 Spatial Analysis: To examine spatial patterns of wetland vegetation parameters in the Credit River Watershed, monitoring sites were grouped into Lower, Middle and Upper zones, with five, five and eight sites established in each zone, respectively (Fig. 2). It is hypothesized that differences in land cover and landscape configuration among the three zones are likely to influence wetland health parameters, including species richness, diversity and floristic quality.

Data were analyzed with STATISTICA 7.0 (Statsoft Inc.), with results considered significant when $p<0.05$ (Zar 1999). Data were tested for normality and homoscedasticity using the Shapiro-Wilk test and Levene's test for homogeneity of variance, respectively. If required, data were transformed in order to improve normality and homogeneity (Appendix B). Where data could not be normalized, the equivalent non-parametric test was used to complete analyses. Repeated measures ANOVA (Analysis of Variance) was used to examine differences in vegetation parameters among the three physiographic zones (Table 3). Tukey's HSD test for unequal sample sizes was used for post-hoc comparisons in order to compensate for the larger number of sites in the Upper zone compared to the Middle and Lower zones (Zar 1999). When a significant interaction is detected between zone and year in the repeated measures ANOVA it is not possible to distinguish the main effects of the parameters (Underwood 1997). In this situation, one-way ANOVAs were completed for each individual year in order to determine differences among the physiographic zones. The Kruskal-Wallis test was conducted on annual data sets to identify differences among the three physiographic zones for non-normalized data. This is a non-parametric version of a one-way ANOVA in which treatment levels of an independent variable (e.g. physiographic zone) are independent of one another. Zone effects had to be analysed on a year by year basis because Kruskal-Wallis cannot account for year effect when all survey years are used in the same analysis. An associated post-hoc test was subsequently run to determine which zone relationships were significant.

2.2.2.3 Correlation between Vegetation Parameters and Landscape Metrics: To increase understanding of the relationships between wetland vegetation populations and the landscape which surrounds them, Spearman Rank correlations were used to determine if monotonic associations exist between vegetation parameters and landscape metrics. Monotonic associations are instances where one variable increases or decreases with the other variable, but not necessarily in a linear manner. Correlations were run pairing the mean of each vegetation parameter across the monitoring period (Table 3) to habitat patch size, distance to nearest road, matrix quality, and finally percent agriculture, natural and urban area within a 2 km radius. Landscape parameters were based on orthophotography collected between 2005 and 2007 over the Credit River watershed. Aerial photographs were interpreted and analysed using ArcGIS, a software package capable of generating information on patterns, structure, and change within a landscape (Credit Valley Conservation Authority 2007a).

Habitat patch is defined as a continuous patch of natural land cover in a given area, in which the monitored wetland area is included, and is comprised of forests, wetlands and successional communities. To calculate percent natural, urban and agricultural area, a 30 m buffer was developed around the centre of the monitoring site, and the percentage of land use for each category was calculated within a 2 km radius from the edge of the buffer. The 30 m buffer was used to develop a centre point which would encompass each wetland site. Finally, matrix quality is an index developed to account for the amount of varying types of land uses in an area, with higher matrix quality values indicating more natural land cover in the area. Matrix influence is calculated by summing percent natural area multiplied by positive one, with percent agricultural area multiplied by zero, and percent urban area multiplied by negative one (TRCA 2007).

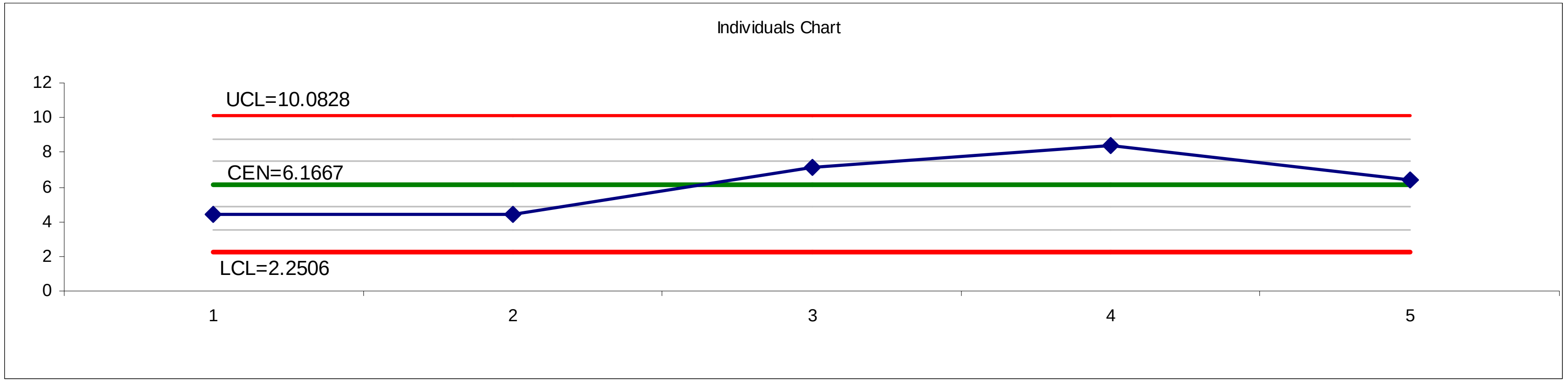
Spearman Rank correlations were completed using STATISTICA 7.0 (Statsoft Inc.), with results considered significant when $p<0.05$. Habitat patch size and distance to the nearest road were included as metrics in the analysis as research has shown that they both tend to negatively affect vegetation communities (Findlay and Houlahan1997; Hooftman and Diemer 2002). A radius of 2 km was chosen for the scope of this urban composition parameter because Findlay and Houlahan (1997) found that landscape effects on wetland taxa richness were strongest when considering composition at this distance. The mean of each vegetation parameter over four years of monitoring was calculated for each site so that correlations could be made between vegetation parameters and landscape metrics. This was necessary because landscape data were not available in a year-by-year form but rather as a single “snapshot” representation of land parameters during the general period of monitoring.

In addition, relationships between the most predominant non-native species with a weediness score of -3 and landscape metrics were also analyzed with logistic regression using STATISTICA 7.0 (Statsoft Inc.). The presence of Purple Loosestrife, Common Buckthorn and Garlic Mustard at each site was tested against habitat patch size, distance to the nearest road, percent natural cover and percent urban cover using simple logistic regression with one continuous predictor. The chosen species were selected according to the same criteria used in the Cochrane-Armitage analyses. Though still considered a parametric option, logistic regression is a non-linear estimation method in which the binary response variable is assumed to follow a binomial distribution (Quinn and Keough 2002). The assumptions of normality and homoscedacticity do not apply as with linear regression. For logistic regression tests between site occupancy (presence/absence) over the five-year survey period and landscape parameters, a site was considered occupied if the species in question was detected in at least two of the four survey years.

2.2.2.4 Statistical Process Control: Statistical Process Control (SPC) is an application which uses time series data to develop thresholds (Maurer et al. 1999). Though similar to regression, SPC is not based on hypothesis testing. Instead, this application seeks to identify instances when a time series exhibits non-random behaviour. A series demonstrating this non-random behaviour is considered “out of control” and, as such, unsuitable for developing a monitoring baseline. If the time series exhibits natural random variability around a reference point (usually the mean), the series is considered “in control”. Data that are in control can be treated as a baseline from which monitoring thresholds can be generated. A recommended minimum of five years of “in control” data have been used to set monitoring thresholds (Paul Zorn, pers. comm.).

SPC control charts are divided into six zones based on the mean value of a time series and its standard deviation adjusted to sample size (Fig. 4). The upper and lower critical limits, defined as +/- 3 standard deviations (SD) from the mean, encompass the “in control” range of the time series. Control charts for stable systems will not contain any points outside the +/- 3 SD “in control” range. In such a case, the series represents appropriate reference conditions from which the +/- 3 SD critical limit thresholds can be adopted. Series with points outside the “in control” range may represent an ecosystem under stress or moving slowly toward some alternate state. A data set in this type of flux would not provide appropriate reference conditions on which thresholds could be based.

For this study Individual Moving Average and Moving Range Charts were examined to determine if each vegetation parameter was in control (Paul Zorn, pers. comm.). Values that exceed the critical limits and are associated with significant increasing or decreasing trends should always be investigated thoroughly. Often in monitoring, early detection of changing trends or a significant decline in parameters is desired in order to recognise problems before the effects become irreversible. To address these early detection concerns, the upper and lower warning limits on control charts are represented by +/- 2 SD from the mean. Trends of series that exceed the warning limits but not the critical limits should be tracked closely for further changes. A time series with values falling within the warning limits is exhibiting natural variability and is considered to be stable and not of concern based on SPC alone. All statistical control charts for vegetation data were generated using SPC XL (SigmaZone), a third-party add-on application to Microsoft Excel.



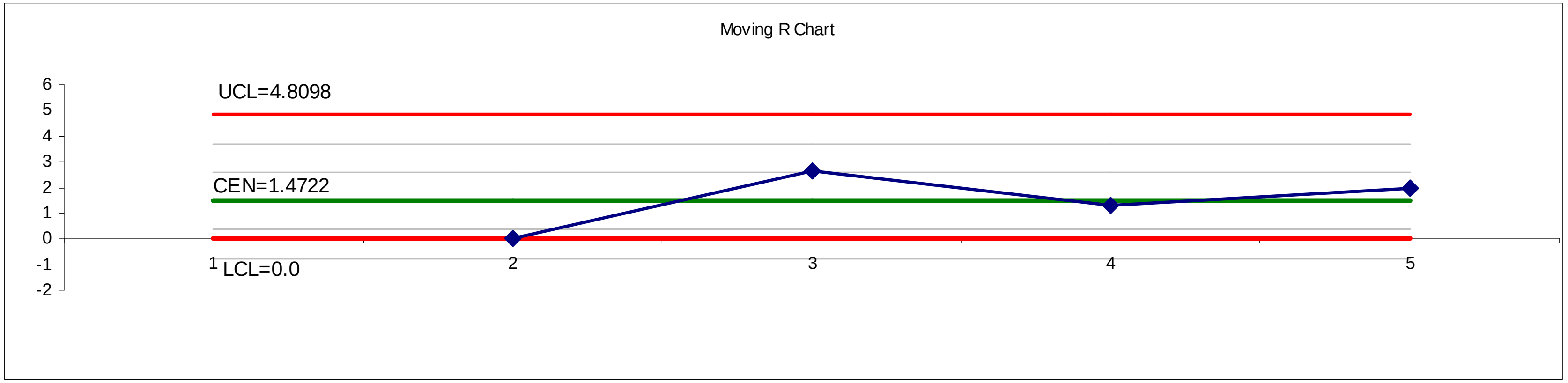


Figure 4. Statistical Process Control charts for weedy species richness. Both the individual moving average chart (showing the parameter values for each year) and the Moving Range chart (showing the amount of change in the parameter between years) are "in control" from 2005 to 2009. On the Individuals Chart, the green line indicates the time series mean and the red lines show the upper and lower critical limits (+/- 3SD). Since the data set is in control, the mean from 2005-2009 can be used as a baseline for future monitoring.

2.2.2.5 Power Analysis: Power analyses were conducted in PASS (NCSS Inc.) to determine the number of monitoring sites required in order to detect significant levels of change in various vegetation parameters. Power analysis also assessed the ability of the current monitoring program to detect statistical differences in wetland vegetation parameters among physiographic zones and among years, given the number of established monitoring sites. Power analysis uses baseline monitoring data to determine if additional monitoring sites are required to detect significant trends. Effect size refers to the detectable change in the time series over a given interval, and is often related to a specific monitoring threshold. Based on SPC, which also uses baseline monitoring data to generate monitoring thresholds, changes in a parameter of ± 1 SD represent natural variability in stable systems and are not considered to be of concern. Changes in a parameter of ± 2 SD are considered outside of normal variability expected in stable communities and represent early warning signs. Changes in a parameter of ± 3 SD represent instability and situations in which causal factors must be investigated. The effect sizes considered in the power analyses have therefore been set at 1, 2 and 3 SD to represent ecologically relevant statistical differences in wetland vegetation communities. Currently, five years of in control data will be used to determine the five year effect size.

In addition to the calculation of required *n*, the minimum effect size that can currently be measured under the monitoring program was determined for each analysis. These results were used to determine the quality of current monitoring data. Data quality was assessed according to Table 4, developed by Dobbie et al. (2006) and CVC. Although these rules are subjective, they are not arbitrary and are based on emerging common practice among conservation agencies, personal experience, and logistical considerations (Dobbie et al. 2006). For linear regression, the upper effect size limit (data are red) is set to 40% because changes above this point are too coarse to provide early warning of decline in a parameter. A change of nearly 50% or greater would be needed before changes were detected by the monitoring program (Dobbie et al. 2006). The lower effect size limit (data are green) is set to 20% because a smaller effect size is too fine and would likely result in an unaffordable monitoring program. An effect size of less than 20% may be reasonable for some parameters, but this is likely not the case for all monitored parameters. And although smaller effect sizes may allow for the detection of significant differences more often, without knowledge regarding natural variability in the parameter it may be difficult to determine if these changes are meaningful (Dobbie et al. 2006). It is important to note that the data quality rules developed by Dobbie et al. (2006) were set according to power analysis of a paired *t*-test. This test does not reflect changes in trends but changes in status and usually requires a smaller sample size to achieve the same power and confidence as a regression test (Dobbie et al. 2006). Therefore, data quality assessment is appropriate, if not more stringent than necessary, for analyses completed in this report.

For the Cochrane-Armitage test, percent change effect sizes could not be calculated; therefore, SD was instead used to determine data quality (Table 4). The upper effect size limit (data are red) was set to 3 SD because that is the critical warning limit in SPC. Therefore, data in this quality range are not capable of detecting the most important ecological changes. The lower effect size limit (data are green) is set to <2 SD because that is the early warning limit in statistical process control. Data in this quality range can therefore detect both early and critical warming limits and should be able to provide managers with necessary information for making informed management decisions. It should be noted that data quality will naturally be better for measures that display more variance over the study period. This is because the critical and warning thresholds are themselves based on the standard deviation of baseline data. For example, it is easier (e.g. requires a smaller sample size) to detect a 2 SD change in mortality when the underlying variability of the mortality data is high. If variability was low, 2 SD would represent a very small change in proportion. Smaller changes are innately more difficult to detect than larger changes over the same time period.

Currently, no type of effect size could be calculated for logistic regression. For that reason, two data quality groupings were developed for this analysis. Data were considered green if enough site-years were available to detect a significant logistic relationship between parameters. Data were considered red if not enough site-years were available to detect a significant logistic relationship between parameters. No yellow data category was used.

Confidence and power levels are also subjectively, but not arbitrarily, selected. Although research standards typically set confidence to 95% and power to 80%, this may not be appropriate for ecological monitoring (Dobbie et al. 2006). Confidence refers to the probability of not committing a Type I statistical error. In ecological monitoring, this may be considered a “false alarm”. Power refers to the probability of not making a Type II error, which may be considered a “missed signal”. In ecological monitoring, missing a signal has more severe management implications than raising a false alarm. For that reason, power is usually set higher than confidence in this type of monitoring (Dobbie et al. 2006).

Table 4. Rule set for assessing data quality in monitoring measures (adapted from Dobbie et al. 2006).

Data Quality	Effect size			Confidence	Power
	Linear Regression	Cochrane-Armitage	Logistic Regression		
Green	<20% change	<2 SD	Currently have enough site to detect a significant relationship	80%	90%
Yellow	>20% <40% change	2-3 SD	N/A	80%	90%
Red	>40% change	>3 SD	Currently do not have enough site to detect a significant relationship	80%	90%

3.0 RESULTS AND DISCUSSION

3.1 DESCRIPTIVE ANALYSIS

3.1.1 Most Common Species

Monitoring Question: What vegetation species were most commonly encountered in the Credit River Watershed?

- The most common species in the watershed were: Red Osier Dogwood, Climbing Nightshade, Marsh Bedstraw, Spotted Touch-me-not, Northern Bugleweed, Brown-seed Dandelion, Fowl Manna-grass, Riverbank Grape, Canada Blue Joint and Wild Mint.

The ten most common combined wetland vegetation species across all years are presented in Table 5 in descending order. The most common wetland species span a range of wetness values from facultative upland to obligate wetland species (+3 to -5). They also occupy a range of Conservation Coefficients, between 0 and 5, indicating that they tolerate major to mild disturbance. Of the top ten species, eight are native to Ontario, whereas Climbing Nightshade (*Solanum dulcamara*) and Brown-seed Dandelion (*Taraxacum officinale*) are non-native.

Two of the most common species, Canada Blue Joint (*Calamagrostis canadensis*) and Marsh Bedstraw (*Galium palustre*), are Species of Urban Interest as designated by Credit Valley Conservation (CVC). This designation is specific to CVC, which has ranked species inhabiting the watershed according to their sensitivity to environmental change and disturbance. Species in the watershed may be ranked as Species of Conservation Concern (SoCC; Tier 1), Species of Interest (SoI; Tier 2), Species of Urban Interest (SoI; Tier 3), Secure (Tier 4) or Non-native (Tier 5). Species of Conservation Concern are designated at risk either federally and/or provincially, or are provincially rare according to OMNR's Natural Heritage Information Centre. According to a draft version of the ranking, a total of 87 species in the Credit River Watershed have been designated SoCC to date. Species of Interest are either uncommon in the watershed and/or have exhibited a significant population decline in the past 25 years. Finally, Species of Urban Interest are exhibiting some form of decline within urban areas due to some sensitivity, but are thought to be relatively secure in more natural environments.

The five most common non-native wetland vegetation species across all years are presented in Table 6 in descending order. In 2009, CVC ranked priority invasive vegetation species into five categories. Species in Category 1, or Transformer species, have the ability to exclude all other species, dominate sites indefinitely and provide a threat to natural areas. Category 2 consists of Highly Invasive Species that tend to dominate certain niches or that are problematic, but do not spread rapidly from major concentrations. These species can persist in dense populations for long periods. Category 3 consists of Moderately Invasive species that can become locally dominant under specific conditions. Category 4 species are considered Minimally Invasive and do not pose an immediate threat to natural areas, but compete with native species. Finally, Category 5 species are Potentially Invasive and are known to reproduce aggressively on occasion, but have not yet posed a serious threat to natural areas in Ontario (Credit Valley Conservation 2009).

Of the most common non-native species recorded in the surveys, Purple Loosestrife, Common Buckthorn, Manitoba Maple (*Acer negundo*) and Garlic Mustard are all considered Transformer species. Additionally, all but Manitoba Maple have a weediness score of -3 according to the Floristic Quality Assessment System for Southern Ontario (Oldham et al. 1995). There is conflicting evidence as to whether or not Purple Loosestrife has the ability to decrease native species richness in wetlands (Hager and McCoy 1998; Farnsworth and Ellis 2001). However, it has been demonstrated that Purple Loosestrife alters nutrient cycling and decomposition rates, posing a major threat to wetland ecosystems (Blossey et al. 2001). Common Buckthorn has many physiological traits which confer advantages over native species. It is shade tolerant, has rapid growth rates and higher photosynthetic rates when compared with many native species (Knight et al. 2007). It also has a large range of habitat tolerances, grows well in drought and moisture rich environments, has high fecundity and high germination rates and has bird dispersal of fruit which allows the shrub to spread rapidly and successfully (Knight et al. 2007). Garlic Mustard is a biennial forb that is shade tolerant and capable of thriving in the understory. Community disturbance is also not required for Garlic Mustard to become established at a site (Rodgers et al. 2008). In addition, Garlic Mustard produces a variety of secondary compounds that make it unpalatable to many herbivores, affect seed germination and growth of surrounding native plants, and alter the activity of soil biota (Rodgers et al. 2008). Manitoba Maple is an aggressively opportunistic tree species which thrives in alluvial soils. It is most commonly found in riparian areas, floodplains and anthropogenic waste areas and tends to shade out herbaceous plants, especially in wetlands (Wisconsin Department of Natural Resources 2004).

Climbing Nightshade is considered a Moderately Invasive species by CVC, as it is known to invade forests and wetlands. Brown-seed Dandelion has not been ranked by CVC, but is considered a -2 species by the Floristic Quality Assessment System. True Forget-me-not (*Myosotis scorpioides*), a garden escapee, is considered a Minimally Invasive species by CVC because it does not pose a threat to natural areas and mainly dominates shaded seepage areas.

In general, the most common ground vegetation species were the same as the most common combined vegetation species, with the exception that in ground vegetation Red Osier Dogwood was the tenth most common species in conjunction with Reed Canary Grass (*Phalaris arundinacea*) (Table 7). The five most common non-native wetland ground vegetation species are also similar to those for combined vegetation, with the exception that Common Buckthorn and Manitoba Maple were absent.

The five most common wetland regenerating species across all years are presented in Table 8 in descending order. Common Buckthorn is the only non-native species appearing on the list. White Elm (*Ulmus americana*) was the only tree species present on the list, while the remaining four species were shrubs. Wetness values ranged from -3 to +3 and CC values ranged from 0 to 3.

Table 5. The ten most common combined vegetation species across all years in the Credit River Watershed.

Common Name	Scientific Name	Native	Wetness Index	SCC Tier	CC Value	Mean # of Sites per Year
Red Osier Dogwood	*Cornus stolonifera*	Native	-3	4	2	16
Climbing Nightshade	*Solanum dulcamara*	Non- Native	0	5	N/A	13.6
Marsh Bedstraw	*Galium palustre*	Native	-5	3	5	12.6
Spotted Touch-me-not	*Impatiens capensis*	Native	-3	4	4	12
Northern Bugleweed	*Lycopus unifloris*	Native	-5	4	5	11.2
Brown-seed Dandelion	*Taraxacum officinale*	Non- Native	3	5	N/A	10.8
Fowl Manna-grass	*Glyceria striata*	Native	-5	4	3	10.6
Riverbank Grape	*Vitis riparia*	Native	-2	4	0	10.6
Canada Blue Joint	*Calamagrostis canadensis*	Native	-5	3	4	9.8
Wild Mint	*Mentha arvensis*	Native	-3	4	3	9.8

Table 6. The five most common non-native combined vegetation species across all years in the Credit River Watershed.

Common Name	Scientific Name	CVC Invasive Priority Category	Wetness Index	Weediness Score	Mean # of Sites per Year
Climbing Nightshade	*Solanum dulcamara*	3	0	-2	13.6
Brown-seed Dandelion	*Taraxacum officinale*	N/A	3	-2	10.8
Common Buckthorn	*Rhamnus cathartica*	1	0	-3	8.2
Purple Loosestrife	*Lythrum salicaria*	1	-5	-3	6.8
Manitoba Maple	*Acer negundo*	1	-2	N/A	5.4
Garlic Mustard	*Alliaria petiolata*	1	0	-3	5.4
True Forget-me-not	*Myosotis scorpioides*	4	-5	-1	5.4

Table 7. The ten most common ground vegetation species across all years in the Credit River Watershed.

Common Name	Scientific Name	Native	Wetness Index	SCC Tier	CC Value	Mean # of Sites per Year
Climbing Nightshade	*Solanum dulcamara*	Non- Native	0	5	N/A	13.6
Marsh Bedstraw	*Galium palustre*	Native	-5	3	5	12.6
Spotted Touch-me-not	*Impatiens capensis*	Native	-3	4	4	12
Northern Bugleweed	*Lycopus unifloris*	Native	-5	4	5	11.2
Brown-seed Dandelion	*Taraxacum officinale*	Non- Native	3	5	N/A	10.8
Fowl Manna-grass	*Glyceria striata*	Native	-5	4	3	10.6
Riverbank Grape	*Vitis riparia*	Native	-2	4	0	10.6
Canada Blue Joint	*Calamagrostis canadensis*	Native	-5	3	4	9.8
Wild Mint	*Mentha arvensis*	Native	-3	4	3	9.8
Reed Canary Grass	*Phalaris arundinacea*	Native	-4	4	0	9.4
Red Osier Dogwood	*Cornus stolonifera*	Native	-3	4	2	9.4

Table 8. The five most common regenerating species across all years in the Credit River Watershed.

Common Name	Scientific Name	Native	Wetness Index	SCC Tier	CC Value	Mean # of Sites per Year
Red Osier Dogwood	*Cornus stolonifera*	Native	-3	4	2	15.8
Choke Cherry	*Prunus virginiana ssp. virginiana*	Native	1	4	2	8
Common Buckthorn	*Rhamnus cathartica*	Non-Native	3	5	N/A	7.2
White Elm	*Ulmus americana*	Native	-2	4	3	6.4
Common Red Raspberry	*Rubus idaeus*	Native	-2	N/A	0	6

3.1.2 Species Richness and Proportion of Natives

Monitoring Questions: How many vegetation species were found in the Credit River Watershed? What proportion of wetland vegetation species was native to the Credit River Watershed?

- Three hundred and seventeen species were detected.
- Seventy-eight percent of these species were native to Ontario.

Over the five year monitoring period 317 woody and herbaceous vegetation species were identified to species level, representing 26% of the 1205 vascular vegetation species known to occur in the Credit River Watershed (Credit Valley Conservation 2002). Seventy-eight percent of the species detected were native to Ontario. Of the species identified, 16% were shrubs, 8% were trees and the remaining 76% were herbaceous plant types (ferns, grasses, forbs, etc.) (Fig. 5). Combined vegetation species richness was highest at Warwick and Caledon Lake Wetlands. Warwick is located within the Middle watershed, and Caledon Lake is located within the Upper Watershed, both on CVC property. The sites with the lowest richness were Meadowvale Wetland and Ken Whillans Wetland, both of which are also on CVC property in the Lower and Middle watershed, respectively.

The proportion of native combined wetland vegetation species, watershed-wide, ranged from 79.8% to 84.6% per year. Between 2005 and 2009, the number of native species increased from 186 to 220 species (18.3%), while the number of non-native species increased from 41 to 49 (19.5%). It therefore appears that the rate of increase for non-native species is similar to the rate of increase of native species. Sites with the greatest proportion of native species were Caledon Lake Wetland and Acton Wetland, within the Upper and Middle watersheds, respectively. Sites with the lowest proportion of native species were Rattray Marsh and Meadowvale Wetlands, both found within the Lower watershed. The proportion of native species detected in wetlands was higher than the proportion of native species found in the watershed overall, as it is estimated that approximately 69% of the flora in the Credit River Watershed is native (Credit Valley Conservation 2009).

From 2005 to 2009, 305 plants identified to species were observed in the ground vegetation layer. Approximately 78% of these species were native to Ontario, while the remaining 21% were non-native. The number of species observed each year ranged from 222 to 298, with natives accounting for 78%-85% of these species (Fig. 6).

Over the five year monitoring period 66 regeneration species were identified to species level, approximately 90% of which were native to Ontario. The proportion of native regeneration species watershed-wide ranged from 82.2% to 87.1% across the monitoring period. Only seven non-native regeneration species were detected: Manitoba Maple, Norway Maple (*Acer platanoides*), Tartarian Honeysuckle (*Lonicera tatarica*), Common Buckthorn, Garden Red Currant (*Ribes rubrum*), Purpleosier Willow (*Salix purpurea*) and European Highbush Cranberry (*Viburnum opulus*).

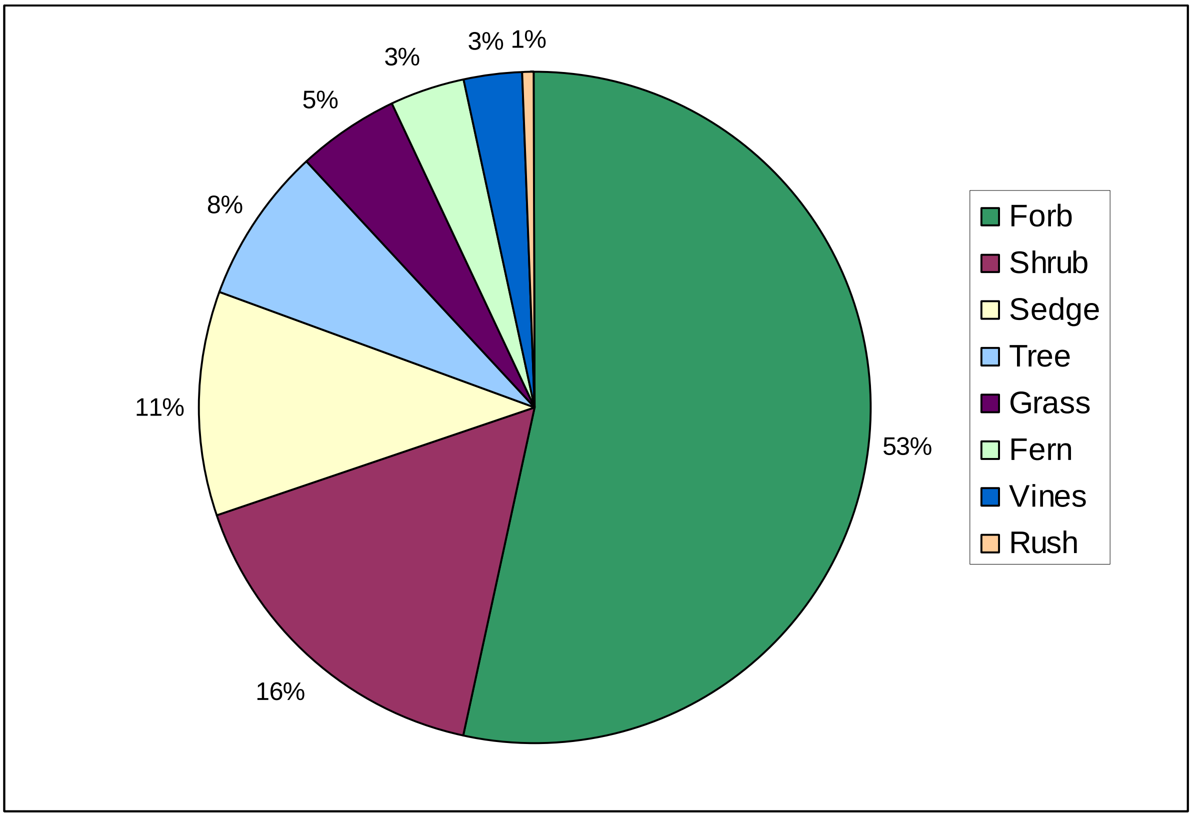


Figure 5. Species richness by plant type detected between 2005 and 2009 in the Credit River Watershed.

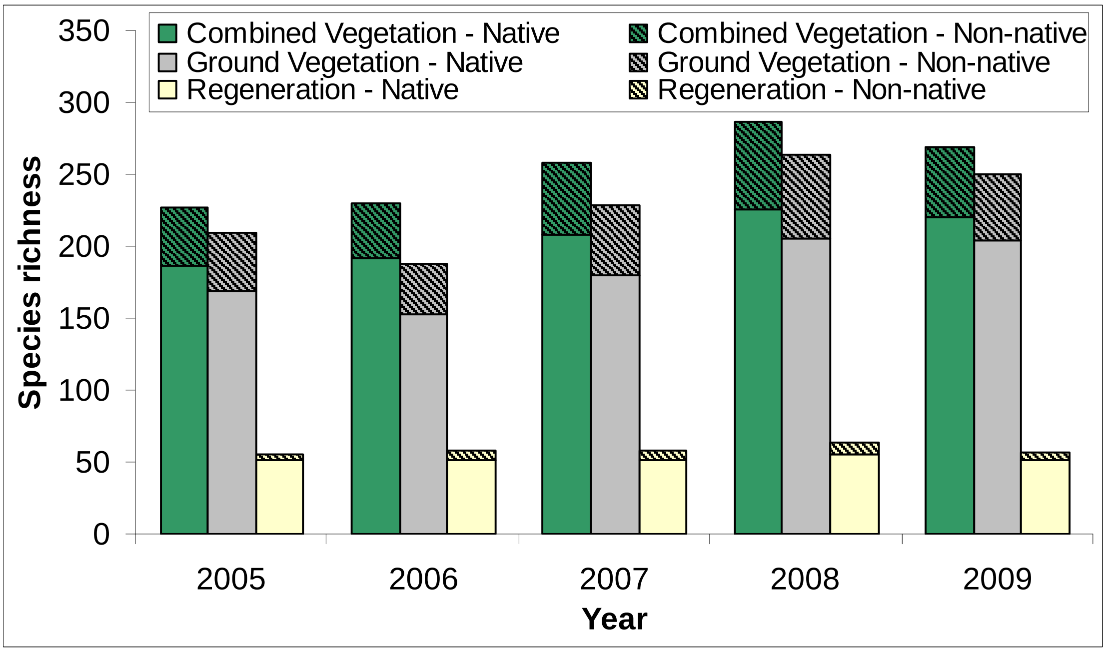


Figure 6. Total species richness throughout the Credit River Watershed over the monitoring period for combined vegetation, ground vegetation and regeneration.

3.1.3 Species Diversity

Monitoring Question: What was the species diversity for ground vegetation and regeneration within the Credit River Watershed?

- Mean total ground vegetation diversity over the monitoring period ranged from 1.32 to 1.83.
- Mean native ground vegetation diversity over the monitoring period ranged from 0.97 to 1.52.
- Mean regeneration diversity over the monitoring period ranged from 0.35 to 0.45.

Because diversity calculations were dependant on cover class estimations and subplot sizes differed between ground vegetation and regeneration, diversity was calculated separately for ground vegetation and regenerating species. However, diversity was not calculated for regeneration in 2009 because of changes in the regeneration sampling protocol which rendered the 2009 incomparable to previous years data.

Over the five year monitoring period, diversity averaged 1.53 and 1.26 per site over the entire watershed for total and native ground vegetation, respectively (Fig. 7). The sites which had the greatest total and native ground vegetation diversity were Grange Orpen Wetland (Total, H' = 2.36; Native, H' = 2.22) and Caledon Lake Wetland (Total, H' = 2.20; Native, H' = 2.11), both located within the Upper Watershed. The sites with the lowest total ground vegetation diversity were Meadowvale Wetland (Total, H' = 0.85; Native, H' = 0.48) and Creditview Wetland (Total, H' = 1.05; Native, H' = 0.61), both located within the Lower watershed.

The mean diversity score per site for regenerating species ranged from 0.35 to 0.45 across the monitoring period (Fig. 7). The sites which had the greatest regeneration diversity were Caledon Lake Wetland (H' = 1.06) and Grange Orpen Wetland (H' = 0.77), both located within the Upper Watershed. The sites with the lowest regeneration diversity were Rattray Marsh (H' = 0.05) and Meadowvale Wetlands (H' = 0.08), both located within the Lower watershed.

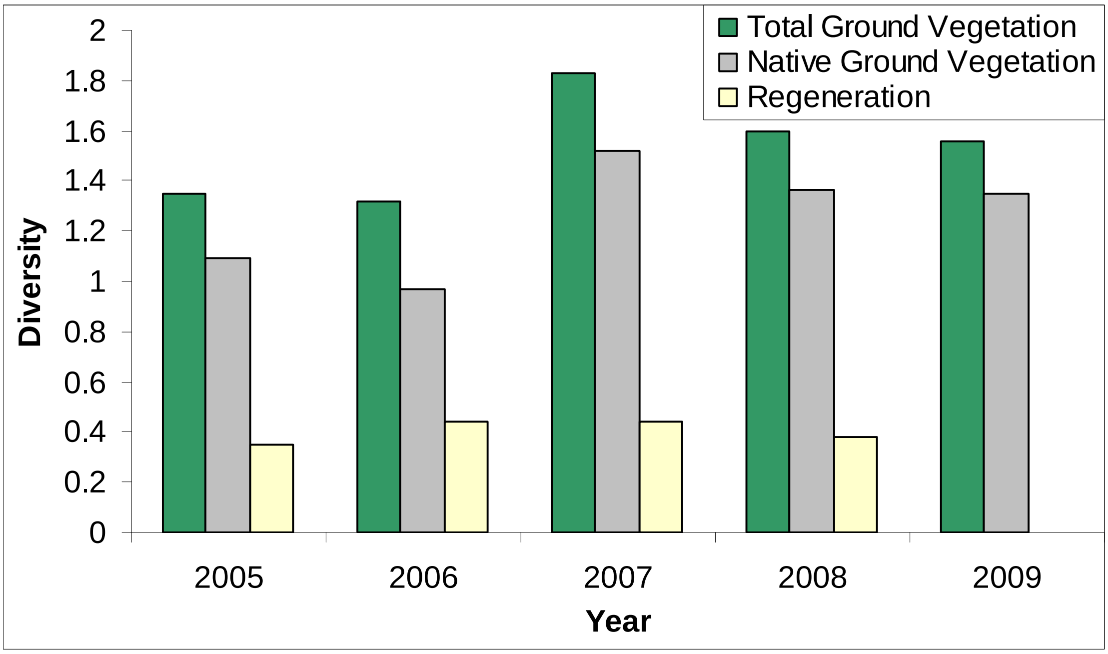


Figure 7. Mean diversity per site throughout the Credit River Watershed over the monitoring period for total and native ground vegetation and regeneration.

3.1.4 Species Evenness

Monitoring Question: What was the species evenness for ground vegetation and regeneration within the Credit River Watershed?

- Mean total ground vegetation evenness over the monitoring period ranged from 0.41 to 0.59.
- Mean native ground vegetation evenness over the monitoring period ranged from 0.48 to 0.66.
- Mean regeneration evenness over the monitoring period ranged from 0.75 to 0.83.

Similar to diversity, evenness calculations were dependant on cover class estimations; therefore evenness was calculated separately for ground vegetation and regenerating species and was not calculated for regeneration in 2009. Over the five year monitoring period, evenness averaged 0.50 and 0.57 per site over the entire watershed for total and native ground vegetation, respectively (Fig. 8). The sites which had the greatest total ground vegetation evenness were Acton Wetland (E = 0.66) and Caledon Lake Wetland (E= 0.60). The sites which had the greatest native ground vegetation evenness were Meadowvale Wetland (E = 0.73) and Terra Cotta Wetland (E= 0.69). The sites with the lowest total and native ground vegetation evenness were Erin Pine Estates Wetland (Total, E= 0.38; Native, E= 0.38) and Warwick Wetland (Total, E= 0.40; Native, E= 0.43). The mean evenness score per site for regeneration species ranged from 0.75 to 0.83 across the monitoring period (Fig. 8). The sites which had the greatest regeneration diversity were Meadowvale Wetland (E = 1.00) and Hungry Hollow Wetland (E = 0.92).

The sites with the lowest regeneration diversity were Caledon Lake (*E* = 0.45) and Belfountain Wetlands (*E*= 0.67).

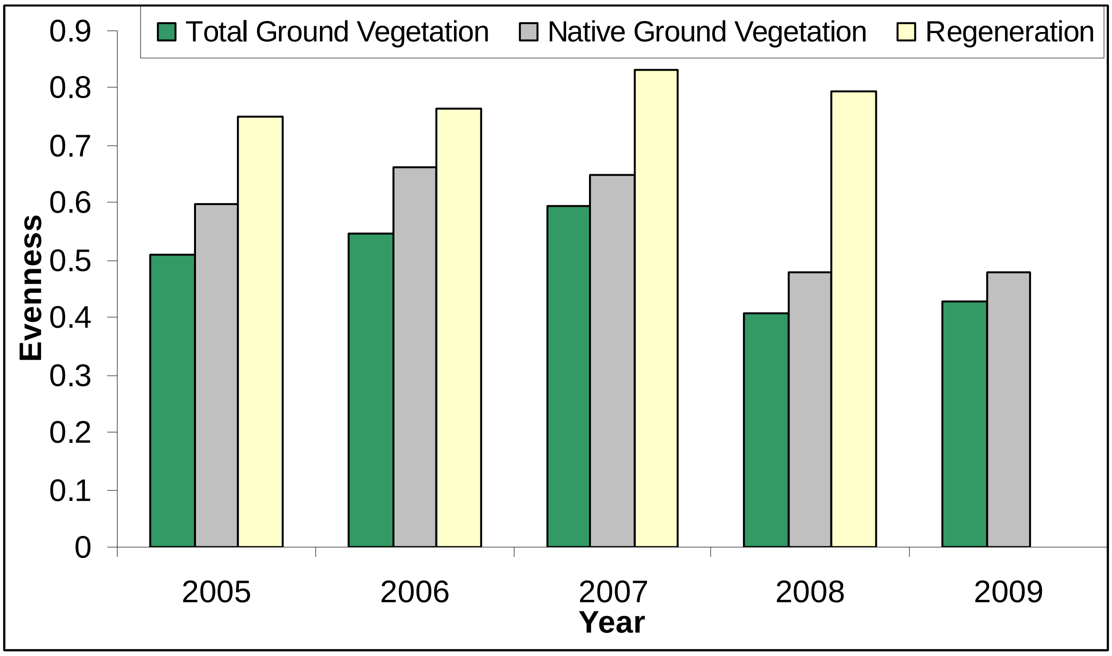


Figure 8. Mean evenness per site throughout the Credit River Watershed over the monitoring period for total and native ground vegetation and regeneration.

3.1.5 Cover Classes

Monitoring Questions: How many species were detected in each cover class? What plant types dominated the different cover classes?

- For ground vegetation, the number of species in each cover class ranged from 271 in the <1% class to 22 in the 76-100% class.
- For regeneration, the number of species in each cover class ranged from 73 in the 1-5% class to 13 in the 76-100% class.
- Ground vegetation was dominated by forbs, while regeneration was dominated by shrubs.

The number of species detected in each cover class ranged from 22 to 271 for ground vegetation and 13 to 76 for regeneration. Species richness tended to decrease from lower classes to higher classes (Fig. 9A & B). In other words, wetland ground vegetation species are more likely to occupy a low proportion of cover within a given area. Forbs were the most dominant plant type in all cover classes in the ground vegetation, making up approximately 55% of the species (Fig. 9A). Rushes were the least represented plant type in all cover classes. For regeneration, shrubs were more dominant than trees in all cover classes (Fig. 9B). This is reflective of monitoring methodology as monitoring plots were not set up in treed locations. Therefore, this does not depict future regeneration trends.

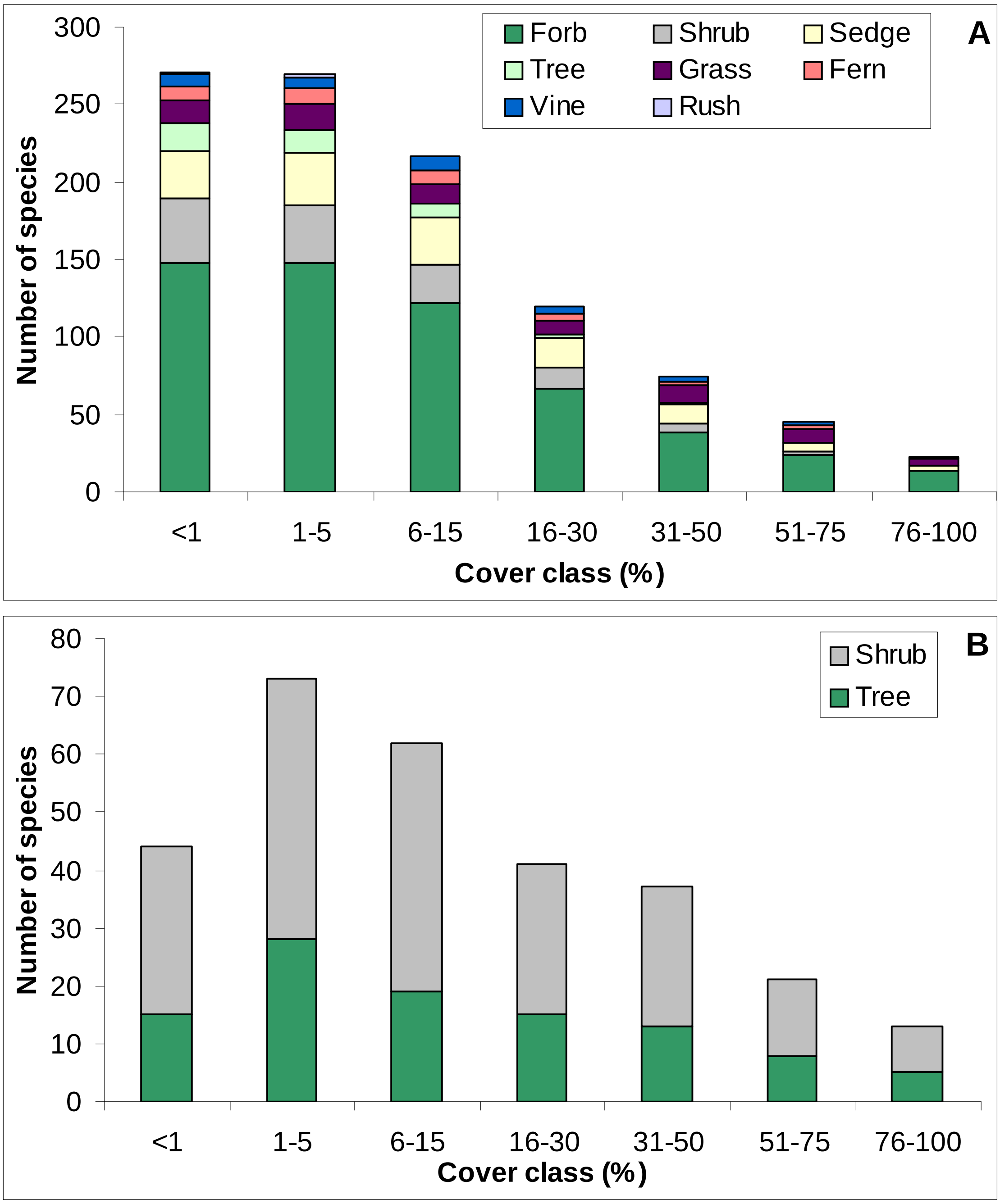


Figure 9. Number of species in each cover class by plant type, for ground vegetation (A) and regeneration (B).

3.1.6 Coefficient of Conservatism

Monitoring Questions: What were the most common coefficient of conservatism (CC) values in the watershed? How many species with a high conservatism score (CC 8-10) were present in the watershed? What was the mean floristic quality index (FQI) value in the watershed?

- The majority of detected species had CC values of between 4 and 6.
- Fifteen species with high CC values were detected.
- mCC scores ranged from 3.91 to 4.08.
- Mean FQI scores ranged from 22.0 to 25.5.

Native wetland plants detected in the Credit River Watershed varied in CC value across the entire range of values, from 0 to 10 (Fig. 10). Species with a score of 0 to 3 are indicative of wide-ranging taxa that are usually tolerant of disturbed sites. Taxa which tolerate mild disturbance have CC rankings of 4 to 6, and those which are found in communities in an advanced successional stage have rankings of 7 to 8. Finally, taxa which tend to be found in pristine communities are assigned a ranking of 9 to 10 (Oldham et al. 1995).

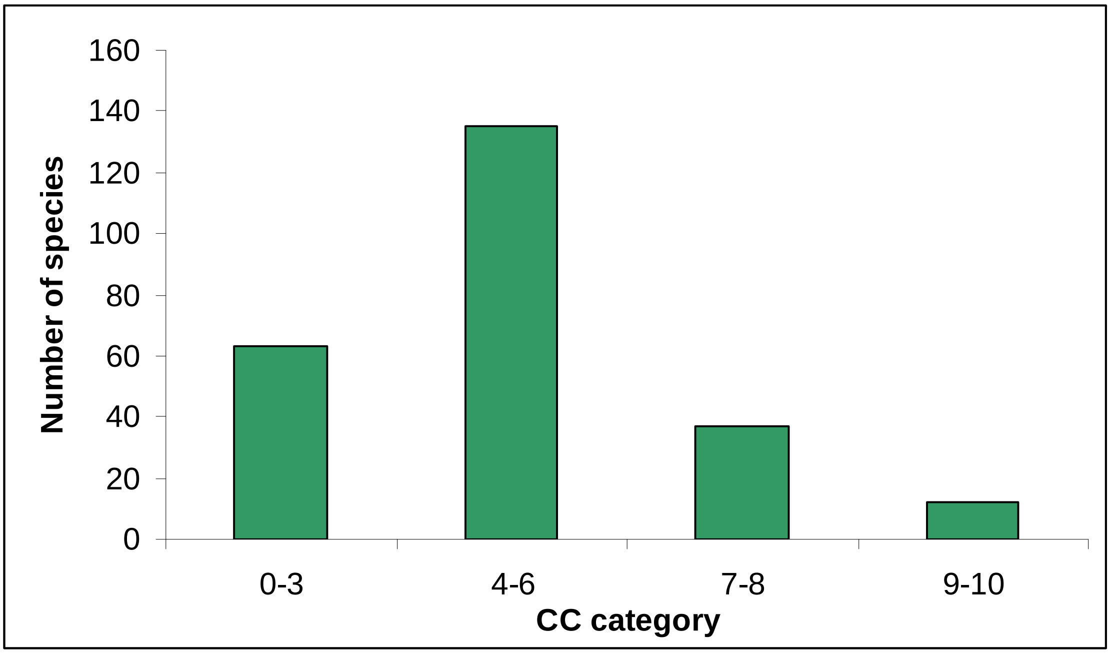


Figure 10. Number of species within each Coefficient of Conservatism (CC) category for plants detected during the monitoring period in the Credit River Watershed.

The CC values for taxa detected across the watershed were used to determine the mean Coefficient of Conservatism for each site (mCC), as well as the Floristic Quality Index of each site (FQI). The mean mCC for sites in each year ranged from 3.91 to 4.08, while the mean FQI for sites in each year ranged from 22.0 to 25.5. Since these two parameters both rely on CC values for their calculation, they were highly correlated with each other among wetland plots ($\rho=0.637$, $p=0.005$). This is consistent with other studies using mCC and FQI, which have shown that these two parameters are highly correlated in natural areas (Bourdaghs et al. 2006; Bowers and Boutin 2008).

Caledon Lake Wetland had the highest mCC (5.76) and FQI (46.7) scores of all sites, which is not surprising as it contains a number of specialized vegetation species which are characteristic of a bog/fen habitat. The sites that contained the lowest mCC scores were Credit River (3.48) and Creditview Wetlands (3.18), while Creditview (15.12) and Meadowvale Wetlands (14.83) had the lowest FQI scores. In general, mCC and FQI ranked sites in a similar fashion in terms of their floristic quality.

Fifteen habitat specialists (CC 8-10) (OMNR 2008), were detected throughout the monitoring period (Appendix C). Each of these species was detected at only one to three sites. Thirteen of the detected habitat specialists were found at Caledon Lake Wetland.

3.1.7 Rare Species

Monitoring Question: How many locally and regionally rare species were found watershed-wide?

- A total of 56 locally and/or regionally rare species were detected.

A total of 55 locally rare species were observed during the monitoring period. Of these species, 31 were also classified as regionally rare. In addition, one regionally rare species, Late Lowbush Blueberry (*Vaccinium angustifolium*), was observed in the watershed. Twenty-four locally/regionally rare species were observed at Caledon Lake Wetland, the most at any monitored wetland in the watershed. Eighteen of these species were not observed at any other monitoring site, including three different species of both *Vaccinium* and *Salix* and 11 known bog/fen indicator species. Warwick Wetland and Erin Pine Estates Wetland had the next highest number of rare species at 11 and eight species, respectively. Meadowvale and Hillsburgh Wetlands had the fewest rare species, with only one present at each site. Each monitored wetland in the watershed contained an average of 5.6 locally and/or regionally rare species. Only one Species of Conservation Concern was detected at monitoring sites: Field Thistle (*Cirsium discolor*); however, it was only observed at Belfountain Wetland in 2005. Approximately 44% of species are considered of interest, while 50% of species are considered secure or non-native (Table 9).

Table 9. Ranking of wetland vegetation species detected in the Credit River Watershed according to CVC's Species of Conservation Concern.

Species of Conservation Concern Ranking	# of Species
Species of Conservation Concern	1
Species of Interest	75
Species of Urban Interest	64
Secure	96
Non-native	66

3.1.8 Wetness Index

Monitoring Question: What was the mean wetness index per site across the watershed?

- Mean wetness index ranged from -1.87 to -2.03.

The mean wetness score averaged across all sites ranged from -1.87 to -2.03 per year. Vegetation detected at monitoring sites in the Credit River Watershed ranged in wetness values from -5 (Obligate Wetland) through +5 (Obligate Upland). The majority (58%) of vegetation species detected ranged from Facultative Wetland to Facultative Upland Species (-4 to +4) (Fig. 11), indicating that they can persist in a range of wet to dry habitats. Thirty-one percent of species detected were Obligate Wetland Species, indicating that they occur almost exclusively in wetlands under natural conditions. The remaining 11% of species detected were Obligate Upland species, indicating that they almost never occur in wetlands under natural conditions. The inclusion of so many Obligate Upland species in the monitoring data is likely due to the fact that the wetland monitoring sites were established along a wetness gradient, beginning in dry areas along the edge of the wetland. The invasion of non-native species may also be a factor, as 59% of the detected obligate upland species were non-native.

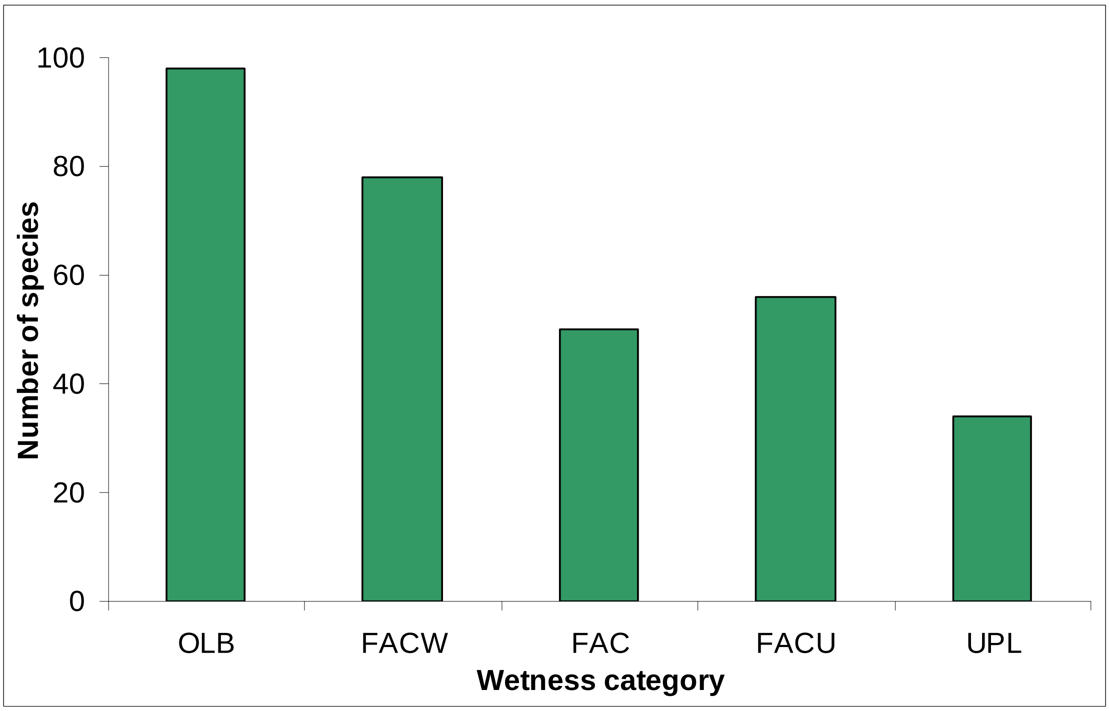


Figure 11. Number of species within each wetness category detected during the monitoring period in the Credit River Watershed. OBL, Obligate Wetland (-5); FACW, Facultative Wetland (-2 to -4); FAC, Facultative (-1 to +1); FACU, Facultative Upland (+2 to +4); UPL, Obligate Upland (+5).

3.1.9 Weediness

Monitoring Questions: What was weedy species richness across the watershed? How many species with a weediness score of -3 were present in the watershed?

- Weedy species richness ranged from 4.44 to 8.39.
- Twelve species had a weediness score of -3.

Sixty-nine non-native plants were detected during the monitoring period (Appendix D), all but five of which have been assigned a Weediness ranking in Ontario by Oldham et al. (1995). Weedy species richness across all sites for each year ranged from 4.44 to 8.39. The sites with the highest weedy species richness across the monitoring period were Credit River and Creditview Wetlands, both located in the Lower watershed. The sites which contained the lowest weedy species richness were Caledon Lake and Speersville Wetlands, both within the Upper watershed.

Forty-one percent of species had a weediness score of -1, suggesting that they have little or no impact on natural areas (Fig. 12). Thirty-five percent of the species detected had a weediness score of -2, indicating that they have the potential to be locally problematic. The remaining 17% of taxa with a score of -3 were considered problematic, or have the potential to become seriously problematic weeds. Nine of the 12 taxa with a weediness score of -3 were detected at three or fewer sites (Table 10).

Detecting problematic non-native species before they are widespread allows for rapid and effective management of invasive species (CFIA 2004). Management efforts may be difficult for species such as Purple Loosestrife, Common Buckthorn and Garlic Mustard as they already appear to be widespread and are found in at least seven sites across the watershed. Species with a more limited distribution, such as Tartarian Honeysuckle, may be easier to control because it has been demonstrated that control is most successful and economical when species are in small populations (Moody and Mack 1988; Welling and Becker 1993; Blossey et al. 2001).

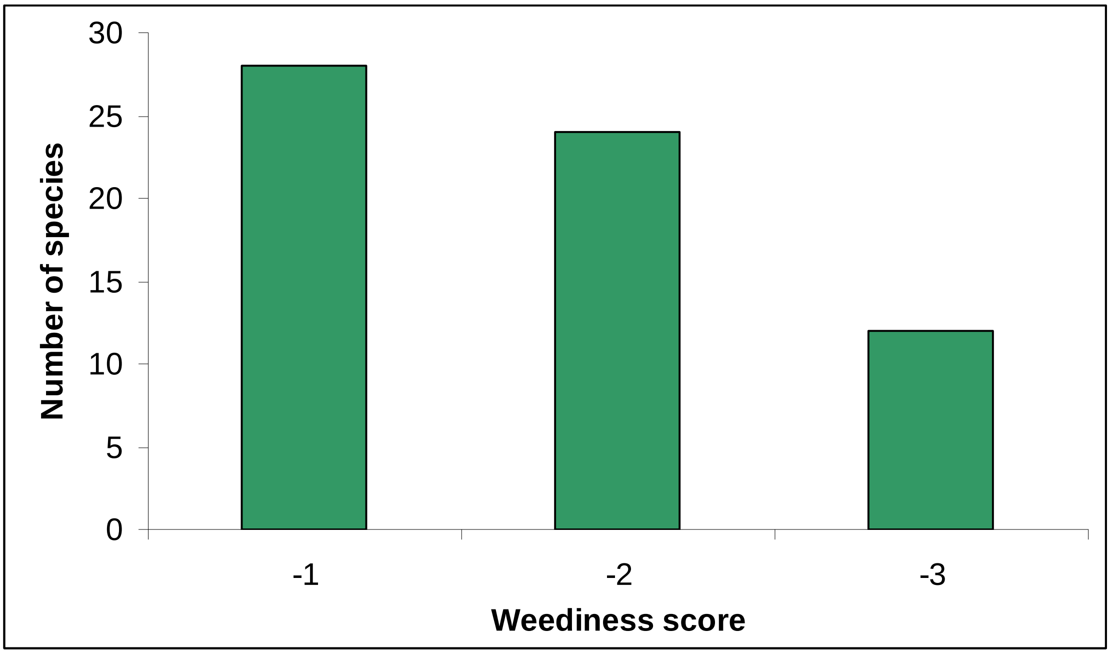


Figure 12. Number of species detected in each weediness category during the monitoring period in the Credit River Watershed.

Table 10. Species detected in the Credit River Watershed between 2005 and 2009 with a weediness score of -3.

Common Name	Latin Name	# Of Sites	Wetness Value
Norway Maple	*Acer platanoides*	1	5
Garlic Mustard	*Alliaria petiolata*	7	0
Greater Celadine	*Chelidonium majus*	1	5
Quackgrass	*Elymus repens*	1	3
Dame’s Rocket	*Hesperis matronalis*	3	5
Common St. John's-wort	*Hypericum perforatum*	3	5
Tartarian Honeysuckle	*Lonicera tatarica*	2	3
Creeping Jennie	*Lysimachia nummularia*	3	-4
Purple Loosestrife	*Lythrum salicaria*	10	-5
White Sweet Clover	*Melilotus albus*	1	3
Curly Pondweed	*Potomogeton crispus*	2	-5
Common Buckthorn	*Rhamnus cathartica*	12	3

3.1.10 Community Composition

Monitoring Questions: Was species composition different among physiographic zones? Did species composition change over the monitoring period?

- Community similarity averaged about 35% between physiographic zones.
- Species turnover at monitoring sites averaged about 17% between years.

Species composition in the Lower zone was 34.1% similar to the Middle zone and 33.6% similar to the Upper zone. Similarity between the Middle and Upper zones was slightly higher at 36.6%. Therefore, although all three zones tended to have relatively dissimilar community composition, the Middle and Upper are more alike than is either to the Lower zone. This is expected due to higher urban cover in the Lower zone. In addition, the Lower zone did not contain any swamps, unlike the Middle and Upper zones. Community similarity values may be more reflective of actual differences with a more balanced sampling design.

Caledon Lake Wetland was the only monitoring site which contained a large number of bog/fen indicator species. The vegetation at Caledon Lake is very different than the other sites, as seen by the large number of rare species present and the large quantity of species which were not observed at other sites. Therefore, Caledon Lake Wetland may not be representative of the majority of wetlands found within the Upper zone. To determine the effect that this site had on community composition, Jaccard's index was recalculated with Caledon Lake removed. This resulted in increased similarity between the Upper and other two zones by 56%. However, removing Caledon Lake from the analyses did not have a significant effect on results; therefore, all results are presented with Caledon Lake included in the analyses.

Similarity in combined community composition between consecutive years ranged from 80.5% to 86.6% (Table 11). Over the entire monitoring period community similarity was 70.5%. Although this indicates that community dissimilarity averaged around 17% between years, the amount of dissimilarity was not increasing between years. Dissimilarity between years can probably largely be attributed to changes in sampling intensity over the monitoring program. However, varying precipitation patterns (Fig. 13) and natural community turnover rate may be responsible for some changes in community composition.

Table 11. Percent community similarity and dissimilarity for combined vegetation watershed wide between years.

Comparison	% Community Similarity	% Community Dissimilarity
2005-2006	80.63	19.37
2006-2007	82.77	17.23
2007-2008	80.46	19.54
2008-2009	86.58	13.42
2005-2009	70.45	29.55

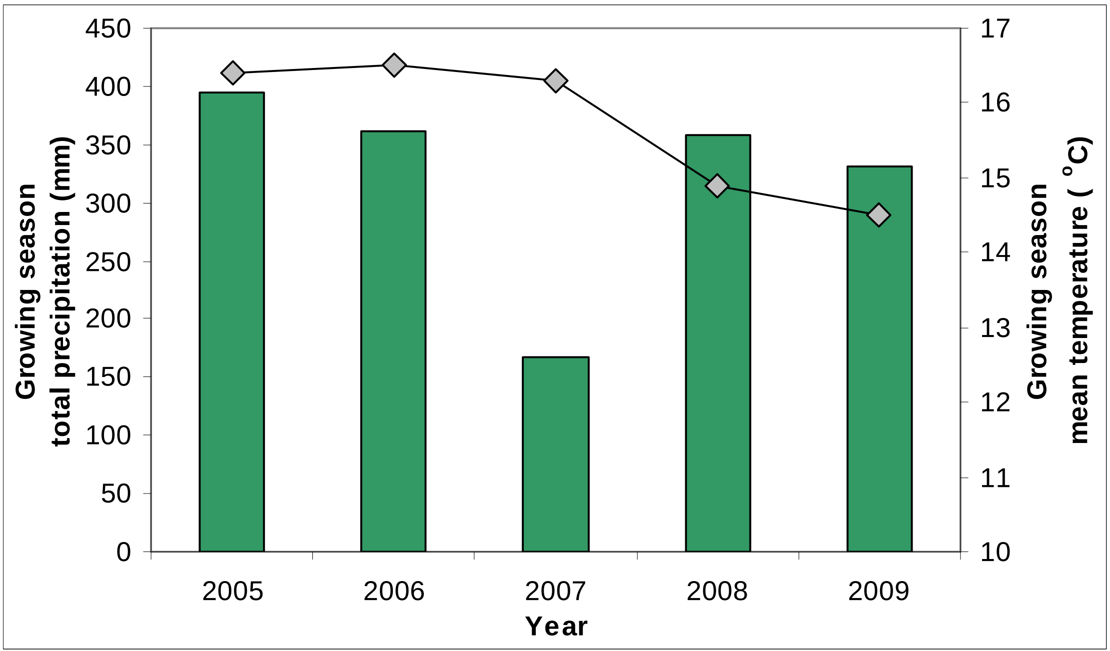


Figure 13. Total monthly precipitation (bars) and mean monthly temperature (points) from 2005 to 2009 in Georgetown, ON during the growing season (April – September). Mean temperature and total precipitation over the growing season were 16.4°C and 395.3 mm, 16.5°C and 360.7mm, 16.3°C and 166.5mm, 14.9°C and 358.0 mm and 14.5°C and 331.1 mm in 2005, 2006, 2007, 2008 and 2009, respectively.

3.1.11 Site Quality

Monitoring Questions: Which sites were the most pristine and most degraded throughout the watershed?

- Caledon Lake, Warwick, Grange Orpen and Erin Pine Estates Wetlands were the most pristine sites in the watershed.
- Creditview, Meadowvale, Winston Churchill and Credit River Wetlands were the most degraded sites in the watershed.

Wetland sites in the Credit River Watershed were ranked based on several wetland vegetation parameters, including: proportion of native species, mCC, number of -3 weedy species and number of rare species (Table 12). Floristic quality index was not included since it is correlated with mCC and would be a redundant parameter. Sites were sorted from the highest to lowest values for each parameter and given a score of between 1 (Highest Quality) and 18 (Lowest Quality). For example, Caledon Lake Wetland had the highest rare species richness, and was given a score of 1 for this parameter. Each site was ranked four times (once for each vegetation parameter) and these scores were summed to give an overall site score. The sites with the lowest score indicated the most pristine habitats. This allowed a coarse determination of which wetland monitoring sites were the most pristine and which sites were most degraded. This is a rough method of ranking the sites, as it assumes that each vegetation parameter contributes equally to the overall quality of the site. The parameters included in the ranking system were chosen because they are broad indicators of wetland health and generally were not affected by sampling quality over the monitoring period. Species richness and diversity were not included in ordering the sites, as it will be affected by wetland community type, but is included in the table for visualization purposes. It is important to note that while this ranking system provides a general overview of site health, the ranking system is subjective.

Caledon Lake, Warwick, Grange Orpen, and Erin Pine Estates were the most pristine wetland sites monitored in the watershed. As stated earlier, Caledon Lake is a very diverse site that contains many bog/fen indicator and rare species and is located in the Upper watershed in a patch of 554.82 ha uninterrupted natural habitat, the second largest habitat patch size of monitored wetlands in the watershed. The remaining three sites are situated in either the Upper or Middle watershed in relatively large habitat patches, are not heavily influenced by urbanization and have relatively highly organic substrates.

Creditview, Meadowvale, Winston Churchill and Credit River Wetlands were the most degraded wetlands monitored in the watershed. All of these sites are located in the Lower watershed and experience heavy pressure from urbanization. It is therefore not surprising that these sites had some of the highest -3 weediness species and lowest percent native species because urbanization is known to increase non-native species in natural areas (McKinney 2006). Creditview and Credit River Wetlands are located in habitat patches of less than 10 ha and are very close to roads and residential areas. Although Winston Churchill and Meadowvale wetlands are situated in relatively large habitat patches, Meadowvale is in very close proximity to a large residential development and was adversely affected by human use and other factors related to urbanization. Similarly, Winston Churchill is situated along the edge of the patch, from which it is largely isolated and connected to only through a riparian corridor. In addition, it is affected by fluctuating water levels, is in very close proximity to a commercial horticultural nursery and may have undesirable placement within the wetland, with the monitoring site starting in a very upland area and ending in open water.

Table 12. Wetland monitoring site quality within the Credit River Watershed. [abc]

Site	Site Name	Physiographic Zone	Wetland Type	% Native	mCC	Count -3	Rare Species Richness	Species Richness	Species Diversity (GV)	
18	Caledon Lake Wetland	Upper	Marsh	0.98	5.76	0.00	17.20	69.40	2.20	
10	Warwick Wetland	Middle	Marsh	0.93	4.28	1.20	5.60	75.60	1.93	Pristine
15	Grange Orpen Wetland	Upper	Marsh	0.94	4.34	0.20	3.20	65.00	2.36	↑
11	Erin Pine Estates Wetland	Upper	Marsh	0.94	4.16	1.40	5.20	68.60	2.17	
7	Acton Wetland	Middle	Marsh	0.94	4.43	0.00	1.20	33.80	1.15	
8	Terra Cotta Wetland	Middle	Swamp	0.87	4.22	0.20	2.40	54.80	1.60	
6	Hungry Hollow Wetland	Middle	Marsh	0.82	3.77	1.20	3.20	48.00	1.74	
20	Belfountain Wetland	Upper	Marsh	0.86	3.91	1.40	2.20	41.00	1.43	
16	Starr Wetland	Upper	Swamp	0.79	3.61	0.20	3.40	55.00	1.70	
19	Melville Wetland	Upper	Swamp	0.78	3.92	1.80	2.60	30.20	1.09	
17	Speersville Wetland	Upper	Swamp	0.93	3.57	0.20	1.20	33.60	1.16	
13	Hillsburgh Wetland	Upper	Marsh	0.84	3.86	1.60	1.20	59.20	1.73	
1	Rattray Marsh Wetland	Lower	Marsh	0.62	4.07	3.00	2.20	34.20	1.47	
9	Ken Whillans Wetland	Middle	Swamp	0.81	3.67	2.20	2.00	28.60	1.29	
2	Credit River Wetland	Lower	Marsh	0.66	3.48	6.00	4.20	50.00	1.41	
12	Winston Churchill Wetland	Lower	Marsh	0.82	3.60	3.20	1.80	34.60	1.21	↓
4	Meadowvale Wetland	Lower	Swamp	0.61	3.93	3.00	0.60	26.20	0.85	Degraded
3	Creditview Wetland	Lower	Marsh	0.63	3.18	3.60	3.80	43.00	1.05	

[a] It is important to note that while this ranking system provides a general overview of site health, the ranking system is subjective.
[b] Parameters represent means across all years for each site.
[c] Green, yellow and orange shading is used to indicate the quality of sites and parameters across the spectrum of most pristine to most degraded. Green shading indicates the highest quality sites/parameters, yellow indicates median ranking of sites/parameters and orange indicates the lowest rankings of sites/parameters.

3.2 TEMPORAL ANALYSIS

3.2.1 Vegetation Parameters

3.2.1.1 Species Richness

Monitoring Question: Did species richness exhibit temporal variation over the monitoring period?

- There was an increasing trend in combined and ground vegetation species richness.
- It appears that regeneration species richness may have been lower in 2009 than other years.

According to linear regression analyses, species richness showed a significant increasing trend between 2005 and 2009 in the Credit River Watershed for both combined and ground vegetation (F=7.466, p=0.008 and F=11.476, p=0.001, respectively; Table 13, Fig. 14A & B). Although p-values for these, and other significant parameters, indicated a significant trend over time, the fitted linear models exhibited low R^2 values indicating that the models explain little of the variation in the data (Table 13).

Temporal differences in species richness could not be determined for ground vegetation, as an interaction was detected in the repeated measures ANOVA; therefore, one-way ANOVAs were completed for each year (results not shown). Differences in species richness were observed among years for combined vegetation and regeneration (F=35.388, p<0.001; F=11.364, p=0.0.23; Table 14, Fig. 15). For combined vegetation, these differences were consistent with the trend analysis. Although the Friedman test indicated differences among years for regeneration, the test does not provide any post-hoc analyses to determine where these differences exist. By examining the means for each year presented in Fig. 15 it appears that regeneration species richness may have been lower in 2009 than other years.

Observed increases in species richness were likely due to improved species identification over the same period. Species identification improved over the course of monitoring due to increased knowledge of the monitoring staff as well as the development of species lists for each site from past years. Additional years of data are needed in order to improve the robustness of the trend analyses.

Table 13. Summary of trend analysis results using linear regression for vegetation parameters between 2005 and 2009.

Vegetation Parameter	*F* value	*p* value [a]	R^2	Observed Trend
Combined Vegetation				
Total Species Richness	7.466	**0.008**	0.068	Increase
Mean Wetness Index	0.001	0.970	-0.011	Stable
mCC	0.031	0.861	-0.011	Stable
Weedy Species Richness	5.104	**0.026**	0.044	Increase
FQI	3.186	0.0778	0.024	Stable
Ground Vegetation				
Total Species Richness	11.476	**0.001**	0.105	Increase
Total Species Diversity	3.923	0.051	0.032	Stable
Native Species Diversity	4.965	**0.028**	0.043	Increase

[a] Results significant when $p<0.05$; significant values highlighted in bold.

Table 14. Summary of temporal analysis results using repeated measures ANOVA or the Friedman test for vegetation parameters between 2005 and 2009.

Vegetation Parameter	Test	*F* value	*p* value [a]	Observed Differences [b]
Combined Vegetation				
Species Richness	Repeated Measures ANOVA	**35.388**	**<0.001**	2005 & 2006 < 2007 & 2009 < 2008
Proportion of Native Species	Friedman	**17.367**	**0.002**	Decreasing from 2005 to 2008
mCC	Repeated Measures ANOVA	**2.645**	**0.042**	2007 < 2009 (p=0.100)
CC 8-10	Friedman	2.554	0.635	None
FQI	Repeated Measures ANOVA	N/A	N/A	Could not be determined
Weedy Species Richness	Repeated Measures ANOVA	**17.677**	**<0.001**	2005 & 2006<2007-2009; 2009<2008
Weediness Count -3	Friedman	**23.305**	**<0.001**	Highest in 2008
Locally Rare	Friedman	**16.366**	**0.003**	Increasing from 2005 to 2008
Regionally Rare	Friedman	5.850	0.211	None
Ground Vegetation				
Species Richness	Repeated Measures ANOVA	N/A	N/A	Could not be determined
Proportion of Native Species	Friedman	**20.919**	**<0.001**	Decreasing from 2005 to 2008
Native Species Diversity	Repeated Measures ANOVA	**31.849**	**<0.001**	2005 & 2006 < 2007-2009; 2009 < 2008
Total Species Diversity	Repeated Measures ANOVA	**40.220**	**<0.001**	2005 & 2006 < 2008 & 2009 < 2007
Native Species Evenness	Friedman	**50.444**	**<0.001**	Higher in 2005-2007 than 2008-2009
Total Species Evenness	Friedman	**47.778**	**<0.001**	Higher in 2005-2007 than 2008-2009
Regeneration				
Species Richness	Friedman	**11.364**	**0.023**	Lowest in 2009
Proportion of Native Species	Friedman	5.922	0.205	None
Total Species Diversity	Friedman	**19.111**	**<0.001**	Increasing from 2005 to 2007
Total Species Evenness	Friedman	**14.012**	**0.003**	Highest in 2007

[a] Results significant when $p<0.05$; significant values highlighted in bold.
[b] Differences between years determined using Tukey's post-hoc test for repeated-measures ANOVA analyses, and by visual observation for the Friedman Test.

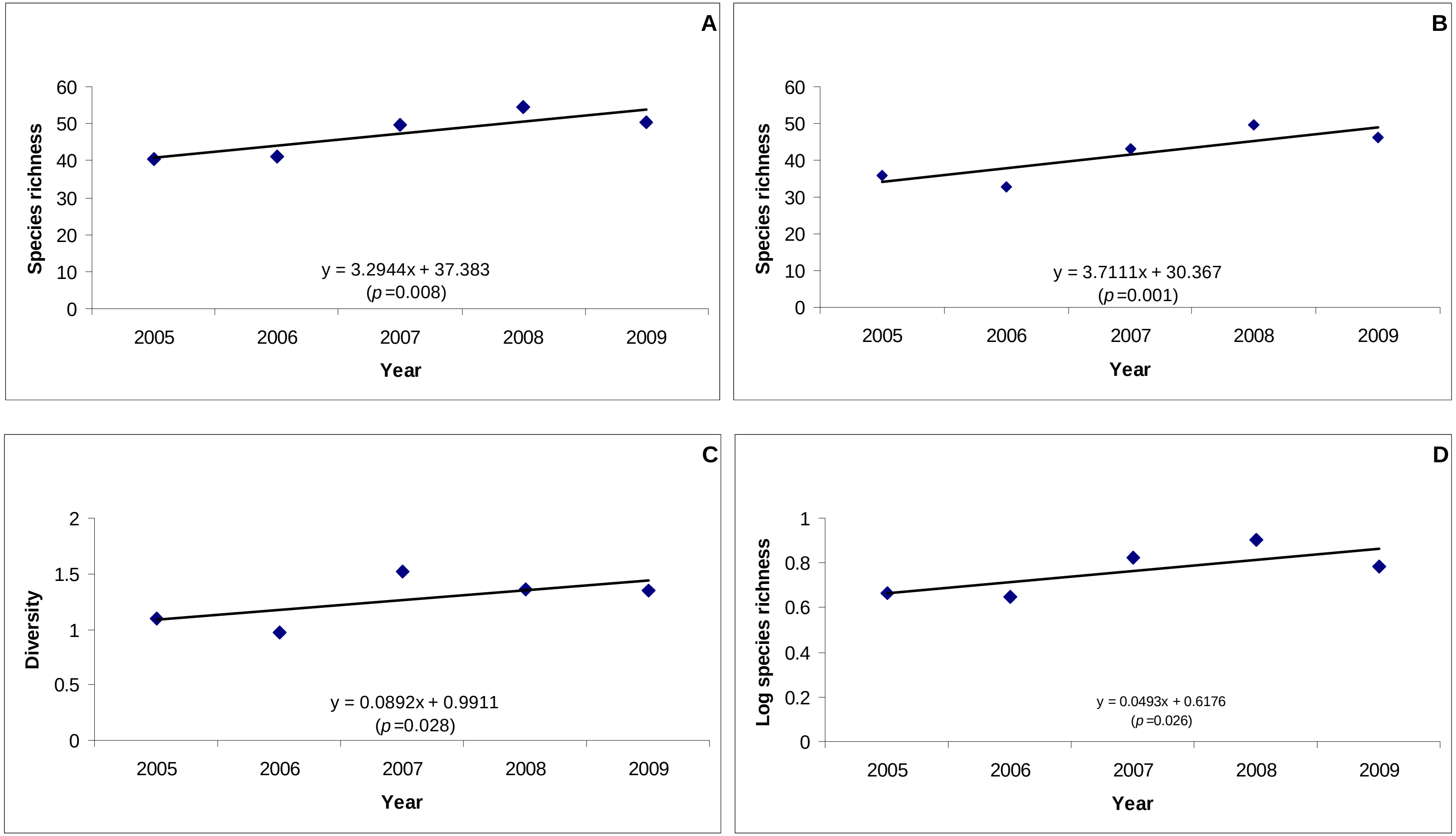


Figure 14. Linear regression for combined vegetation species richness (A), ground vegetation species richness (B), ground vegetation native species diversity (C) and weedy species richness (D) observed at 18 wetland sites in the Credit River Watershed between 2005 and 2009. Points represent the mean over the watershed for each year. Equation of the regression line and *p*-value provided. Weedy species richness was log transformed for analysis and is presented in this way.

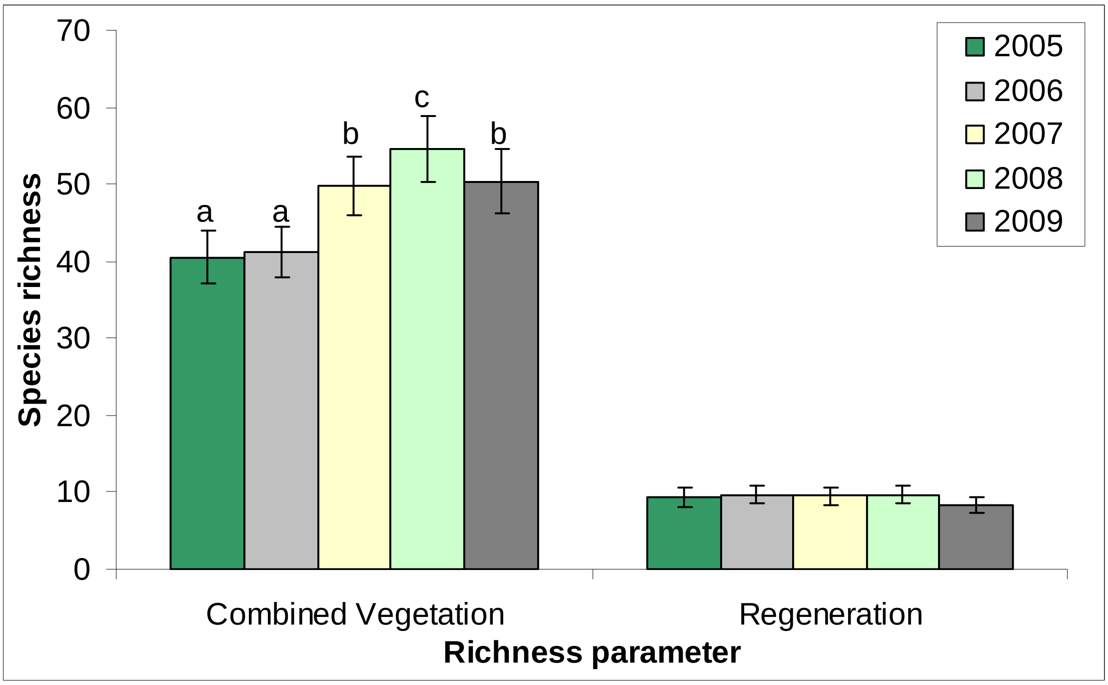


Figure 15. Mean species richness across all sites, as affected by year, for combined vegetation and regeneration. Repeated measures ANOVA was used for combined vegetation, while the Friedman test was used for regeneration. Within vegetation parameters, bars with different letters indicate a significant difference according to Tukey's HSD test for unequal sample sizes (p<0.05). Error bars indicate +/- SE.

3.2.1.2 Proportion of Native Species

Monitoring Question: Did the proportion of native species exhibit temporal variation over the monitoring period?

- The proportion of native species in both combined and ground vegetation appeared to decrease from 2005 to 2008 and increase in 2009.
- For regeneration no differences were observed between years.

Linear regression analysis was not completed on the proportion of native species parameters due to the ordinal natural of the data. The proportion of native species differed among years for combined vegetation and ground vegetation, but not regeneration (F=17.367, p<0.002; F=20.919, p<0.001; F=5.922, p=0.205, respectively; Table 14, Fig. 16). Although the Friedman test indicated differences among years for all three parameters, the test does not provide any post-hoc analyses to determine where these differences exist. By examining the means for each year presented in Fig. 16 it appears that combined and ground vegetation displayed the same pattern, with proportion of native species decreasing from 2005 to 2008 and then increasing again in 2009. The differences seen in the combined and ground vegetation may indicate an increase in non-native species within the watershed over the monitoring period. However, due to the increase in the proportion of natives in 2009, inconsistencies in species naming in the early stages of the program and improved sampling quality in the later years, it is difficult to tell if these changes are due to sampling inconsistencies, increased non-natives or a combination of both factors. This highlights the importance of additional years with improved monitoring accuracy.

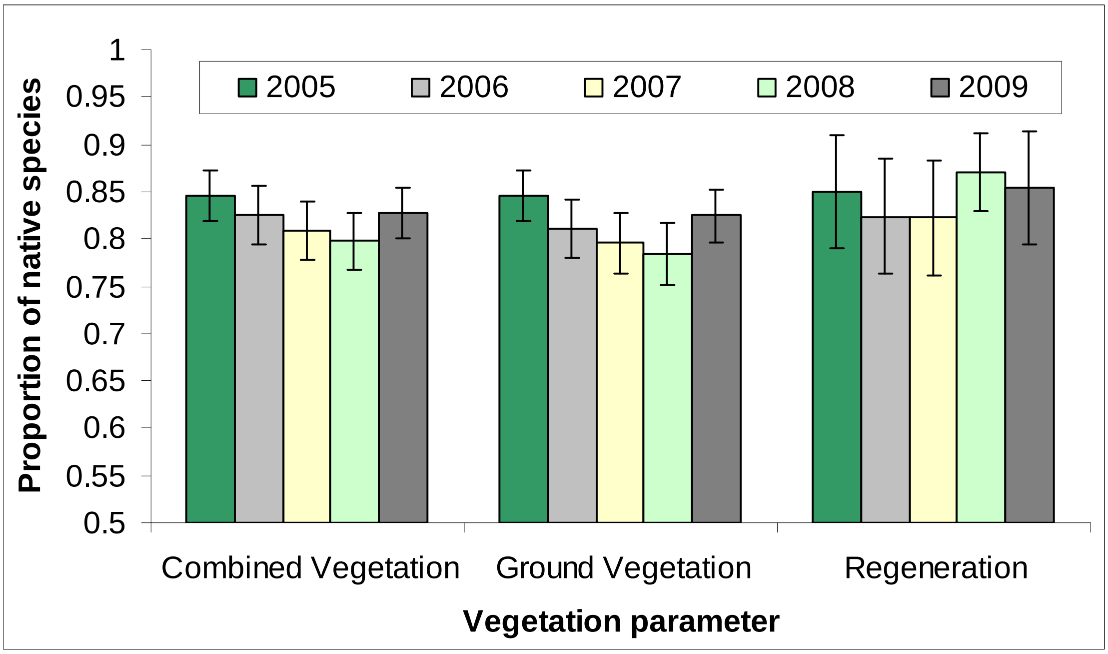


Figure 16. Mean proportion of native species across all sites, as affected by year, for combined vegetation, ground vegetation and regeneration. Friedman test was used for all parameters. Error bars indicate +/- SE.

3.2.1.3 Species Diversity

Monitoring Question: Did species diversity exhibit temporal variation over the monitoring period?   - There was a nearly significant increasing trend in total ground vegetation diversity over the monitoring period.   - Native ground vegetation species diversity significantly increased over the monitoring period.   - Regeneration diversity appeared to increase from 2005 to 2007.

According to linear regression, native ground vegetation species diversity increased over the five year monitoring period (F=4.965, p=0.028; Table 13, Fig. 14C). Total ground vegetation diversity was found to be stable over the monitoring period, although there was a nearly significant positive trend (F=3.923, p=0.051; Table 14). Temporal differences in total and native ground vegetation and regeneration diversity are presented in Fig. 17 (F=40.220, p<0.001; F=31.849, p<0.001; F=19.111, p<0.001, respectively; Table 14) and are generally consistent with the increasing trends observed in the regression analysis. Similarly to species richness, these increasing trends may be attributed to improved sampling. The decrease in 2008 and 2009 for all parameters may be attributed to the different system used to classify percent cover in these years (actual percent cover, as opposed to cover class), as percent cover was used in the diversity calculations.

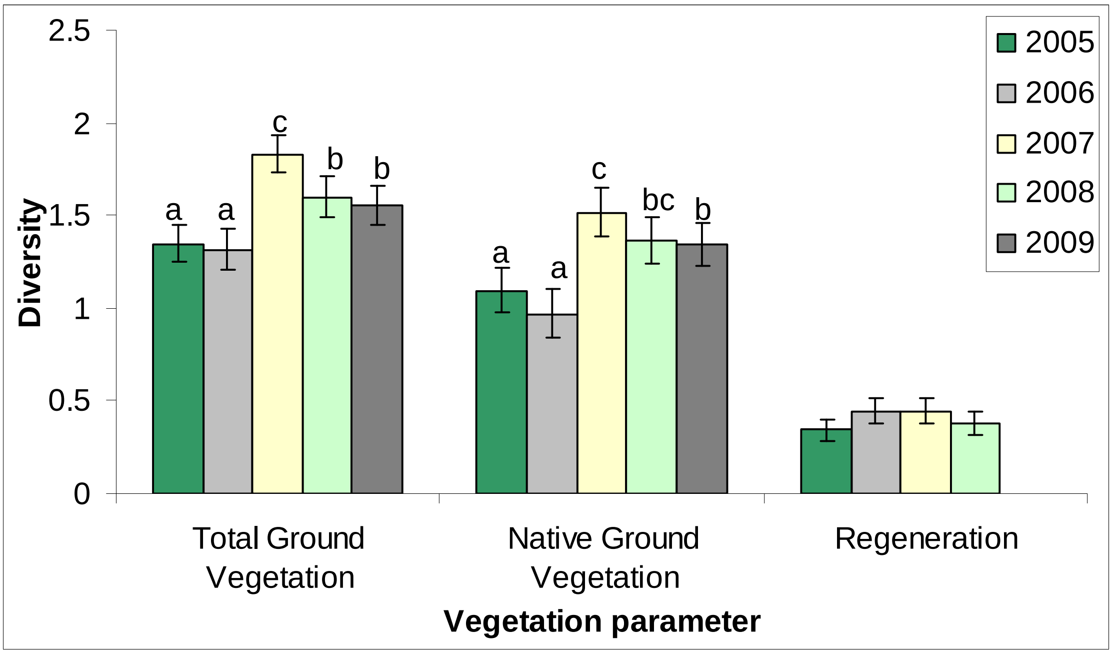


Figure 17. Mean diversity across all sites, as affected by year, for total and native ground vegetation and regeneration. Repeated measures ANOVA was used for total and native ground vegetation, while the Friedman test was used for regeneration. Within vegetation parameters, bars with different letters indicate a significant difference according to Tukey's HSD test for unequal sample sizes (p<0.05). If no letters are present, post-hoc analyses were unavailable to detect difference among years. Error bars indicate +/- SE.

3.2.1.4 Evenness

Monitoring Questions: Did species evenness exhibit temporal variation over the monitoring period?

- Total and native ground vegetation evenness appeared higher in the first three years of monitroing.
- Regeneration evenness appeared highest in 2007.

Linear regression analysis was not completed on the evenness parameters due to the ordinal natural of the data. Differences in total and native ground vegetation and regeneration evenness are presented in Fig. 18 (F=50.444, p<0.001; F=47.778, p<0.001; F=14.012, p=0.003, respectively; Table 14). Evenness for both total and native ground vegetation appeared higher in the first three years of sampling (2005 to 2007) than in 2008 and 2009. In addition, it appeared that evenness for regeneration was highest in 2007. This indicates that cover was more evenly distributed between species in the earlier sampling years. The apparent lower evenness in 2008 and 2009 may signify that either some species are becoming more dominant or that more species which occupy lower cover levels are appearing in the later years. This may be the case and could be the result of improved sampling. In conjunction, the lower evenness levels in 2008 and 2009 for all parameters may be due to the different system used to classify percent cover, similar to diversity. Overall, with additional years of reliable monitoring data, the reasons for these differences may become clearer.

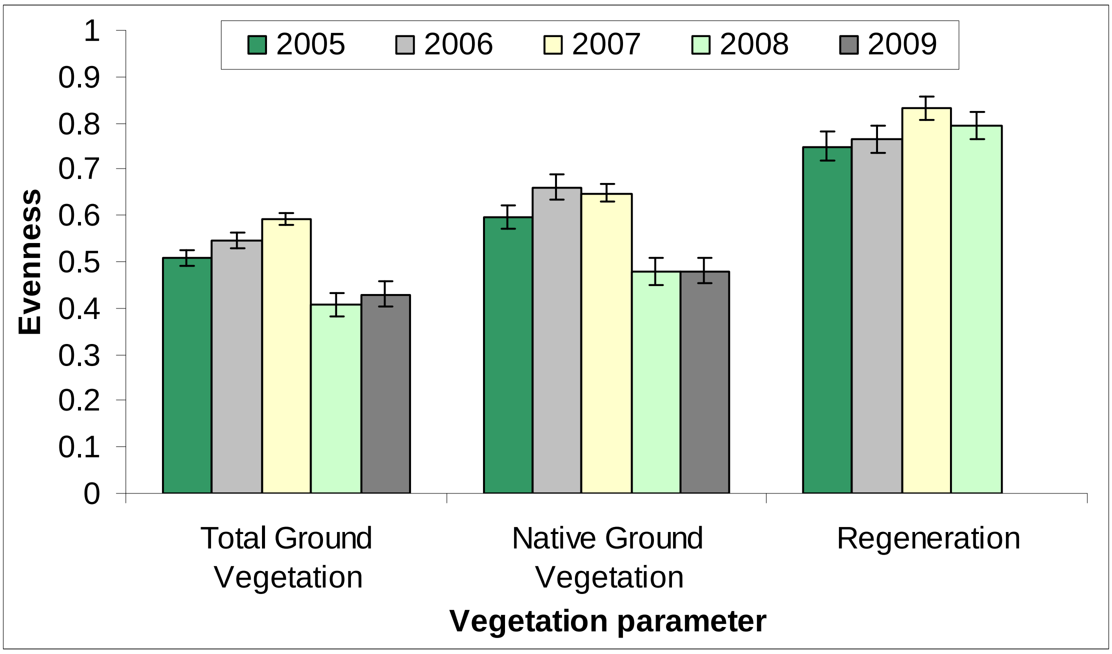


Figure 18. Mean evenness across all sites, as affected by year, for total and native ground vegetation and regeneration. The Friedman test was used for all analyses. Error bars indicate +/- SE.

3.2.1.5 Coefficients of Conservatism

Monitoring Questions: Did mCC and CC 8-10 exhibit temporal variation over the monitoring period? Did FQI exhibit temporal variation over the monitoring period?

- No trends were observed for mCC or FQI.
- There were no differences between years for CC 8-10.

Regression analyses were completed for mCC and FQI, but no significant trends were observed (Table 13); linear regression analysis could not be completed for CC8-10. Temporal analyses were also unable to detect differences in mCC, FQI and CC 8-10. Although the Repeated Measure ANOVA test indicated a significant difference between years for mCC (F=2.645, p=0.042; Table 14), post-hoc analyses were unable to detect these differences, which is consistent with regression results. Temporal differences in FQI could not be determined, as an interaction was detected in the repeated measures ANOVA; and therefore, one-way ANOVAs were completed for each year (results not shown). The number of species with a CC value between 8 and 10 did not differ among years (F=2.554, p=0.635; Table 14, Fig. 19). Therefore, it appears that the floristic quality of monitored sites within the watershed may have been relatively stable over the monitoring period.

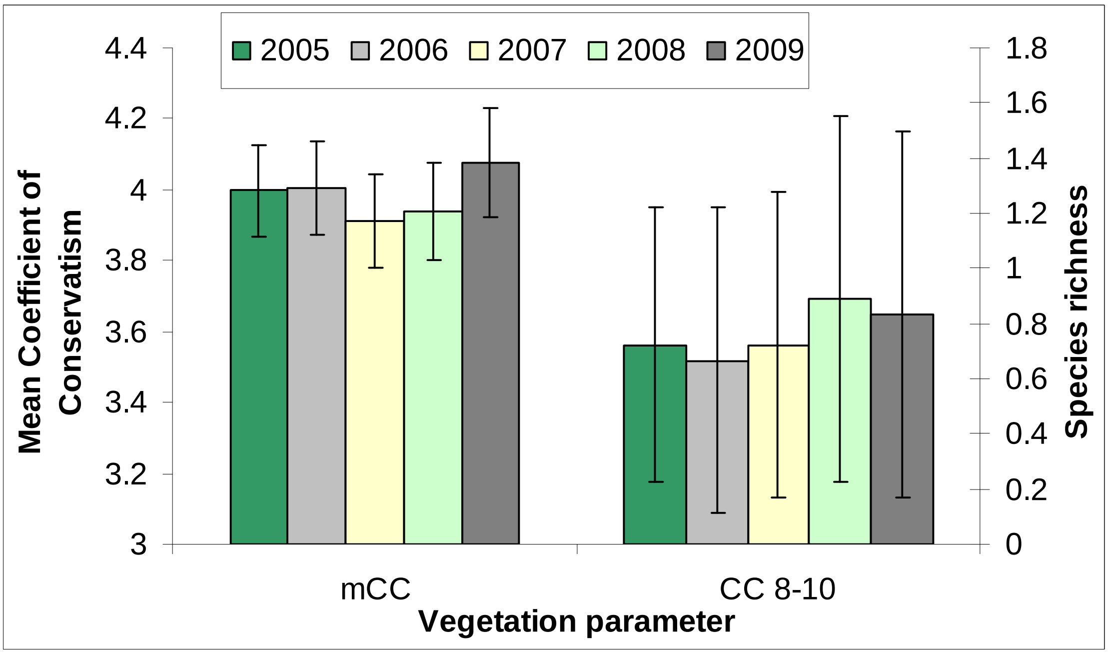


Figure 19. Mean mCC and CC 8-10 across all sites, as affected by year. Repeated measures ANOVA was used for mCC, while the Friedman test was used for CC 8-10. Error bars indicate +/- SE.

3.2.1.6 Weediness

Monitoring Question: Did the weedy species richness and weediness score -3 exhibit temporal variations over the monitoring period?

- Weedy species richness increased over the monitoring period.
- Weediness score -3 appears highest in 2008.

Linear regression analysis was not completed for weediness score -3; however, weediness score -3 differed among years (F=23.305, p<0.001; Table 14, Fig. 20). Due to the use of the Friedman test, significant differences between years could not be determined. It did appear that the number of -3 weediness species steadily increased from approximately one species per site in 2005 to approximately two species per site in 2008. This increase is consistent with the decrease in proportion of native species observed over the years in combined and ground vegetation (Fig. 16) and may indicate that very weedy species are becoming more common in the watershed. It is unlikely that the increase in weediness score -3 was due to improved sampling quality over the years because the majority of -3 species, such as Garlic Mustard, Purple Loosestrife and Common Buckthorn are relatively easy to identify.

Weedy species richness was found to increase from 2005 to 2009 (F=45.104, p=0.026; Table 13, Fig. 14D). Temporal differences between years are consistent with this (F=17.677, p<0.001; Table 14, Fig. 20). The increasing trend observed for weedy species richness may also be a result of improved sampling. However, analyses indicate that the proportion of native species and weediness count -3 were higher in the later years of the monitoring program than the early years. Therefore, the cause of this trend is unclear.

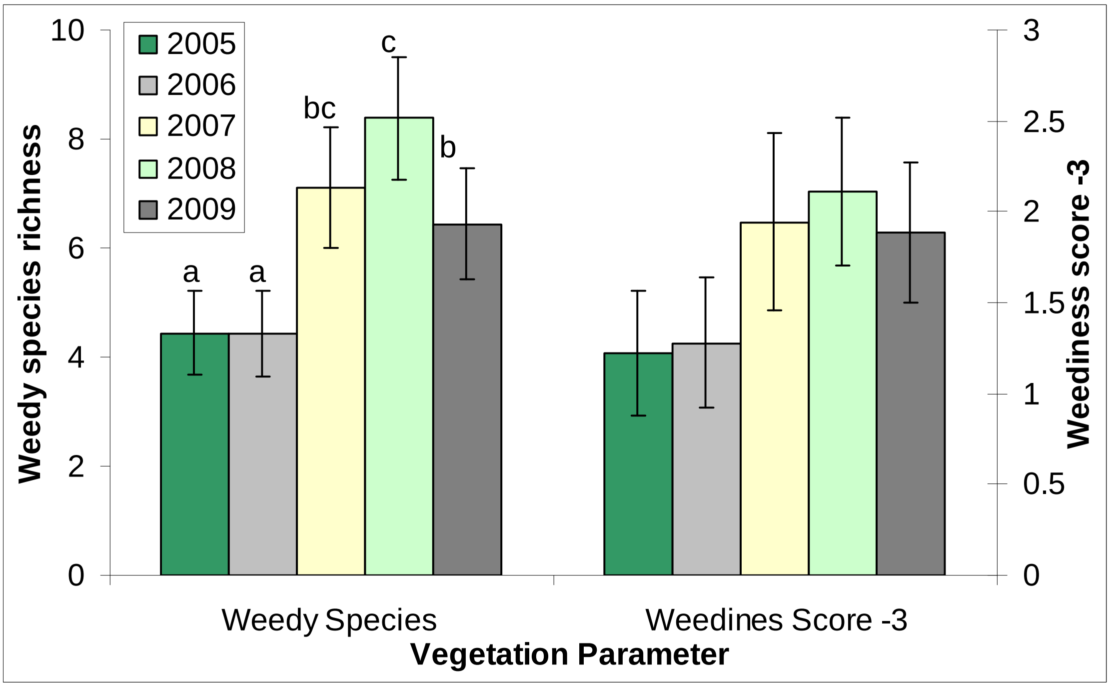


Figure 20. Mean weedy species richness and weediness score -3 across all sites as affected by year. Repeated measures ANOVA was used for weedy species richness, while the Friedman test was used for weediness score -3. Within vegetation parameters, bars with different letters indicate a significant difference according to Tukey's HSD test for unequal sample sizes (p<0.05). If no letters are present, post-hoc analyses were unavailable to detect difference among years. Error bars indicate +/- SE.

It is suggested that wetlands may be vulnerable to invasions, likely due to the fact that they are landscape sinks (Zedler and Kercher 2004). Landscape sinks facilitate invasions through accumulating debris, sediments, water, and nutrients that create canopy gaps or accelerate the growth of opportunistic vegetation species. Many wetland invaders form monotypes which can alter habitat structure, nutrient cycling and food webs, in addition to decreasing biodiversity (Zedler and Kercher 2004). However, over 60% of the species detected with a weediness score of -3 had a wetness value of two or higher (Table 10). This indicates that these species were facultative or obligate upland species, including Common Buckthorn which was the most widespread species with a -3 weediness score. Wetland monitoring sites were established along the hydrological gradient of each wetland, from driest to wettest conditions. For that reason, the first pair of subplots at each monitoring site was often situated on the edge of the wetland, where it was drier and very weedy. Therefore, weedy species may be becoming more dominant along the edges of wetlands in the watershed and special attention should be paid to this trend.

3.2.1.7 Rare Species

Monitoring Question: Did the number of locally rare and regionally rare species exhibit temporal variations over the monitoring period?   - Locally rare species appeared to increase from 2005 to 2008, while no change was seen in regionally rare species.

Linear regression analysis was not completed for rare species parameters. The number of locally rare species per site differed among years (F=16.366, p=0.003; Table 14, Fig. 21). However, no differences were observed among years for regionally rare species (F=5.850, p=0.211; Table 14, Fig. 21). Although a post-hoc test to differentiate years was not available for the Friedman test, it appears that locally rare species increased from 2005 to 2008. In 2008, two rare orchids were recorded at monitoring sites which were not previously observed. These include Small Yellow Lady's-slipper (*Cypripedium parviflorum var. makasin*) at Hungry Hollow Wetland and Northern Green Orchid (*Platanthera hyperborea var. hyperborean*) at Terra Cotta Wetland. The large increase in 2008 may also have been due to improved data collection and entry. Species identification improved over the monitoring period and in 2008 a consultant was commissioned to assist in species identification. This may have culminated in more rare species being identified that year.

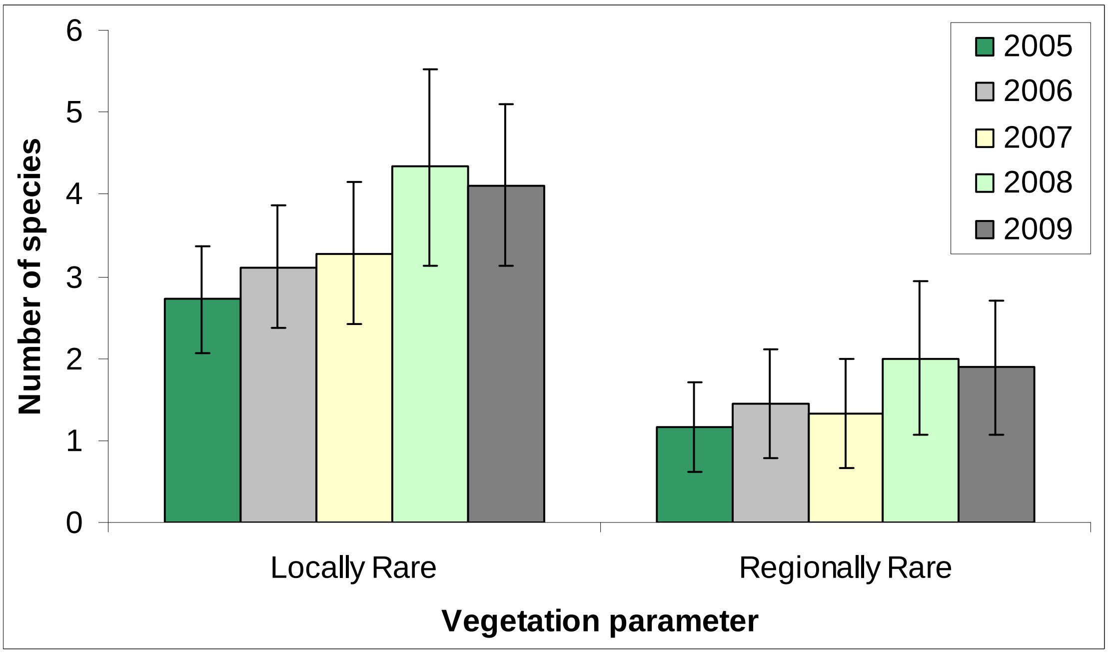


Figure 21. Mean number of locally and regionally rare species across all sites, as affected by year. Friedman's test was used for both parameters. Error bars indicate +/- SE.

3.2.1.8 Power Analysis and Statistical Process Control: For all vegetation parameters analyzed with a linear regression, power analysis determined that the following number of sites would be needed in order to detect 1, 2 and 3 SD of change: 31.8, 7.2 and 2.6 sites, respectively. Therefore, a sufficient number of sites were monitored to detect significant changes in the vegetation parameters with 90% power at an 80% confidence level for effect sizes greater than or equal to 2 SD. This is important because changes in the magnitude of 2 SD are often used as a warning threshold in statistical process control and changes in the magnitude of 3 SD are often used as the critical threshold. A change of 1 SD cannot currently be detected for any of the vegetation parameters. Detectable effect size in the form of percent change varied markedly among the parameters. Detection of less than 5% change is possible for only mCC; changes of at least 5-10% can be detected for mean wetness index and FQI; changes of over 30% can be detected for the weediness parameters; changes of between 10% and 30% can be detected for the remaining parameters (Table 15). Although minimum detectable percent change was as high as 36.5%, this is below the 40% change limit indicating poor data quality. Data quality for all parameters was either green or yellow indicating that data collected by the monitoring program thus far is of good or moderate quality.

Table 16 lists the critical and warning limits calculated for each wetland vegetation parameter. These upper and lower limits will be adopted as monitoring thresholds to which future vegetation monitoring data can be compared. Future values that exceed the upper or lower warning limits will signify emergence of possible increasing or declining population trends, while values that exceed the upper and lower critical limits will signify a significant deviation from natural variability. Such deviations would warrant immediate management action before trends became irreversible. No monitoring thresholds can be applied to those parameters deemed to be out of control or those displaying no variance over the monitoring period.

Table 15. Power analysis results for detecting effect sizes for trend analyses. Values represent the minimum effect size detectable under current monitoring conditions.

Parameter	Minimum Detectable Effect Size (% Change)	Data Quality
Combined Vegetation		
Species Richness	17	Green
Mean Wetness Index	5.1	Green
mCC	2.5	Green
CC 8-10	13	Green
FQI	9.1	Green
Weedy Species Richness	36.5	Yellow
Weediness Count -3	32.6	Yellow
Locally Rare	25.6	Yellow
Regionally Rare	28.7	Yellow
Ground Vegetation		
Species Richness	22	Yellow
Total Species Diversity	16.3	Green
Native Species Diversity	23.8	Yellow

Table 16. Monitoring thresholds for all wetland vegetation parameters extracted from Statistical Process Control individual moving average (IMR) charts for data collected from 2005 through 2009. Limits are presented in the specific units used to measure each given parameter.

Parameter	Lower Critical Threshold	Lower Warning Threshold	Upper Warning Threshold	Upper Critical Threshold
Combined Vegetation				
Species Richness	35.15	39.19	55.35	59.38
Proportion of Native Species	0.769	0.786	0.856	0.873
Mean Wetness Index	-2.19	-2.11	-1.77	-1.7
mCC‡	3.81	3.87	4.11	4.16
FQI	21.04	21.94	25.52	26.41
CC 8-10	0.545	0.619	0.915	0.988
Locally Rare	2.29	2.7	4.32	4.73
Regionally Rare	0.79	1.05	2.09	2.34
Weedy Species Richness	2.25	3.56	8.78	10.08
Weediness Count -3	0.95	1.2	2.18	2.43
Ground Vegetation				
Species Richness	25.95	31.13	51.87	57.05
Total Species Diversity	0.98	1.16	1.9	2.08
Total Species Evenness	0.303	0.368	0.626	0.69
Native Species Diversity	0.7	0.87	1.63	1.82
Native Species Evenness	0.411	0.465	0.683	0.737
Proportion of Native Species	0.744	0.767	0.857	0.881
Regeneration				
Species Richness	7.99	8.43	10.21	10.65
Species Diversity	*Not enough data*			
Species Evenness	*Not enough data*			
Proportion of Native Species	0.781	0.802	0.886	0.906

3.2.2 Species Level Analysis

Monitoring Question: Were trends observed for individual wetland vegetation species over the monitoring period?

- The number of sites at which Common Buckthorn was present in the ground vegetation increased over the monitoring period; however, this may be due to sampling quality.
- No other selected species displayed any trends.

Trends were examined for selected wetland vegetation species using the Cochrane-Armitage test. Ground vegetation species examined included: Garlic Mustard, Common Buckthorn and Purple Loosestrife (Table 17). The only species which exhibited a trend over time was Common Buckthorn, which was present at two sites in 2005 and seven sites in 2009. It is possible that the increase in Common Buckthorn was due to improved monitoring quality. Very young Common Buckthorn plants may be easily confused with young Spotted Touch-me-not (*Impatiens capensis*) plants or may have been disregarded as too young to identify in the early years of the program. No other selected species exhibited an increasing or decreasing trend over time. Therefore, it does not appear that the presence of very weedy non-native species in monitoring sites increased over the monitoring period.

Power analysis and SPC were completed for species evaluated with the Cochrane-Armitage test (Table 17 & 18). Power analysis revealed that under the current monitoring program, data quality is generally poor using the Cochrane-Armitage test to examine trends in species occurrence (Table 17). It appears that examining trends in individual species site occupancy may have limited utility within the current monitoring program, as a larger sample size is needed to detect changes of 2 SD (warning threshold). Therefore, it may be necessary for the current monitoring program to re-evaluate its current methodology for examining individual species trends, to yield results which are meaningful for ecological management.

Statistical process control indicated that data for Purple Loosestrife is not in control and therefore no baseline thresholds could be set for this species at this time. In contrast, data for Common Buckthorn and Garlic Mustard were determined to be in control, resulting in the development of thresholds that may be used for future analysis.

Table 17. Cochrane-Armitage results for selected species trends and power analysis between 2005 and 2009.

Vegetation Parameter	Cochrane-Armitage Test			Power Analysis				
	Critical Z	Observed Z	*p* value	N [a] 1 SD	N [a] 2 SD	N [a] 3 SD	Minimum Effect Size (SD)	Data Quality
Common Buckthorn	1.96	2.138	0.033	79	36	22	4.2	Red
Purple Loosestrife	1.96	1.384	0.166	107	50	31	5.6	Red
Garlic Mustard	1.96	1.139	0.255	132	63	40	6.8	Red

[a] Number of sites required to detect the specified amount of change.

Table 18. Statistical Process Control (SPC) results for selected species trends between 2005 and 2009.

Vegetation Parameter	Lower Critical Threshold	Lower Warning Threshold	Upper Warning Threshold	Upper Critical Threshold
Common Buckthorn	0.104	0.166	0.412	0.474
Purple Loosestrife	*Not in control*			
Garlic Mustard	0.152	0.201	0.399	0.448

3.3 SPATIAL ANALYSIS

3.3.1 Species Richness

Monitoring Question: Did species richness differ among physiographic zones?

- Species richness was unaffected by physiographic zone.

Repeated measures ANOVA analysis of ground vegetation richness revealed a significant interaction between year and zone. When an interaction is present, interpretation of the main effects (year and zone) are impossible, as the two factors are not independent (Underwood 1997). Therefore, when an interaction was detected, one-way ANOVA analyses were conducted separately for each year to examine differences among physiographic zones.

There was no difference detected in combined wetland vegetation species richness among the physiographic zones (F=1.544, p=0.246; Table 19). The mean number of species detected annually was between 17.6 and 25.8 in the Lower watershed, between 31 and 48.2 in the Middle watershed, and between 38.6 and 52 in the Upper watershed. Although not significant, the Lower zone consistently contained lower richness than the other two zones (Fig. 22). There were also no differences among physiographic zones when ground vegetation and regeneration were analyzed separately (F=2.222, p=0.143, F=1.044, p=0.593, respectively; Table 19).

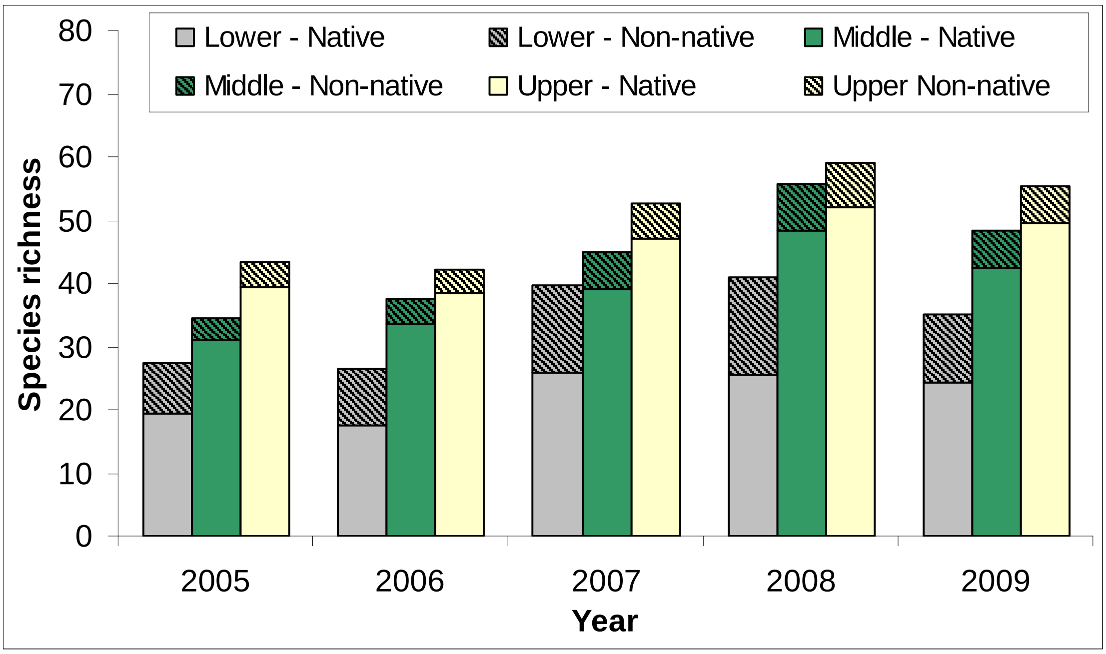


Figure 22. Mean species richness across sites within each physiographic zone in the Credit River Watershed.

Table 19. Summary of spatial analysis results using repeated measures ANOVA or the Kruskal-Wallis test for vegetation parameters between 2005 and 2009.

Vegetation Parameter	Physiographic Effect		Physiographic Differences
	F	***P*** [d]	
Species Richness			
Combined Vegetation	1.544	0.246	None
Ground Vegetation	2.222	0.143	None
Regeneration [ab]	1.044	0.593	None
Proportion of Native Species			
Combined Vegetation [a]	**6.906**	**0.032**	Lower < Upper
Ground Vegetation [a]	**7.456**	**0.024**	Lower < Middle & Upper
Regeneration [ab]	4.077	0.130	None
Diversity			
Total Ground Vegetation [c]	2.831	0.091	None
Native Ground Vegetation	3.665	0.051	None
Regeneration [ab]	4.972	0.083	None
Evenness			
Total Ground Vegetation [c]	2..233	0.328	None
Native Ground Vegetation	2.284	0.319	None
Regeneration [ab]	3.583	0.167	None
Floristic Quality Assessment			
Weedy Species Richness	**4.309**	**0.033**	Lower > Upper (*p*=0.054)
Weediness Count -3 [a]	**8.781**	**0.012**	Lower > Middle & Upper
mCC	1.689	0.218	None
CC 8-10 [a]	2.062	0.357	None
FQI	2.588	0.108	None
Locally Rare [a]	0.508	0.776	None
Regionally Rare [a]	2.509	0.285	None

[a] Kruskal Wallis test conducted for each year separately to test for effect of physiographic zone, with *H* and *p* values shown for 2009 tests only.
[b] Regeneration parameters exhibit spatial autocorrelation and were analyzed with non-parametric methods.
[c] Year by zone interaction present in repeated measures ANOVA. One way ANOVAs performed for each year separately, with F and *p*-values displayed for 2009 only.
[d] Results significant when $p<0.05$; significant values highlighted in bold.

Species richness of vegetation in wetlands has previously been shown to decrease in developed landscapes (Lougheed et al. 2008). Therefore, it was surprising that no differences were observed among physiographic zones. A possible explanation is that non-native species are often imported into urban environments. This increase in non-native species could increase the diversity and abundance of urban species to levels that are similar to surrounding natural environments (McKinney 2006).

Unequal distribution of marsh and swamp monitoring sites throughout the watershed is another possible reason that differences in species richness were not observed among physiographic zones. Richness estimates are expected to be heavily influenced by wetland type, and the current unequal representation of wetland types among physiographic zones may be obscuring biological differences among the zones.

3.3.2 Proportion of Native Species

Monitoring Question: Did the proportion of native species differ among physiographic zones?

- The Lower zone contained a lower proportion of native species than the Middle and/or Upper zone.

The proportion of native species differed among zones across the monitoring period (Table 20). For combined and ground vegetation the Lower zone generally had a significantly lower proportion of natives than the Middle and/or Upper zone (Table 20, Fig. 23A & B). For regeneration, similar differences were seen in three of five years (Table 20, Fig. 23C). The Middle and Upper zones did not contain significantly different proportions of native species (Table 20, Fig. 23C).

Table 20. Kruskal-Wallis test results for differences in the proportion of native species among physiographic zones.

Parameter	Year	Test Statistic (*H*)	*p*-value [a]	Zone Differences [b]
Combined Vegetation	2005	8.494	**0.014**	Lower-Upper (p=0.019)
	2006	9.075	**0.011**	Lower-Middle (p=0.046) Lower-Upper (p=0.014)
	2007	8.001	**0.018**	Lower-Upper (p=0.020)
	2008	9.653	**0.008**	Lower-Middle (p=0.028) Lower-Upper (p=0.013)
	2009	6.906	**0.032**	Lower-Upper (p=0.035)
Ground Vegetation	2005	7.944	**0.019**	Lower-Upper (p=0.023)
	2006	9.997	**0.007**	Lower-Middle (p=0.036) Lower-Upper (p=0.009)
	2007	8.548	**0.014**	Lower-Upper (p=0.015)
	2008	10.263	**0.006**	Lower-Middle (p=0.023) Lower-Upper (p=0.009)
	2009	7.456	**0.024**	Lower-Upper (p=0.026)
Regeneration	2005	7.228	**0.027**	Lower-Upper (p=0.046)
	2006	5.120	0.077	None
	2007	6.114	**0.047**	Lower-Upper (p=0.063)
	2008	9.184	**0.010**	Lower-Upper (p=0.013)
	2009	4.077	0.130	None

[a] Results significant when p<0.05; significant values highlighted in bold
[b] p-values in this column represent the results of post-hoc analyses between the indicated zones. Significant at p<0.05.

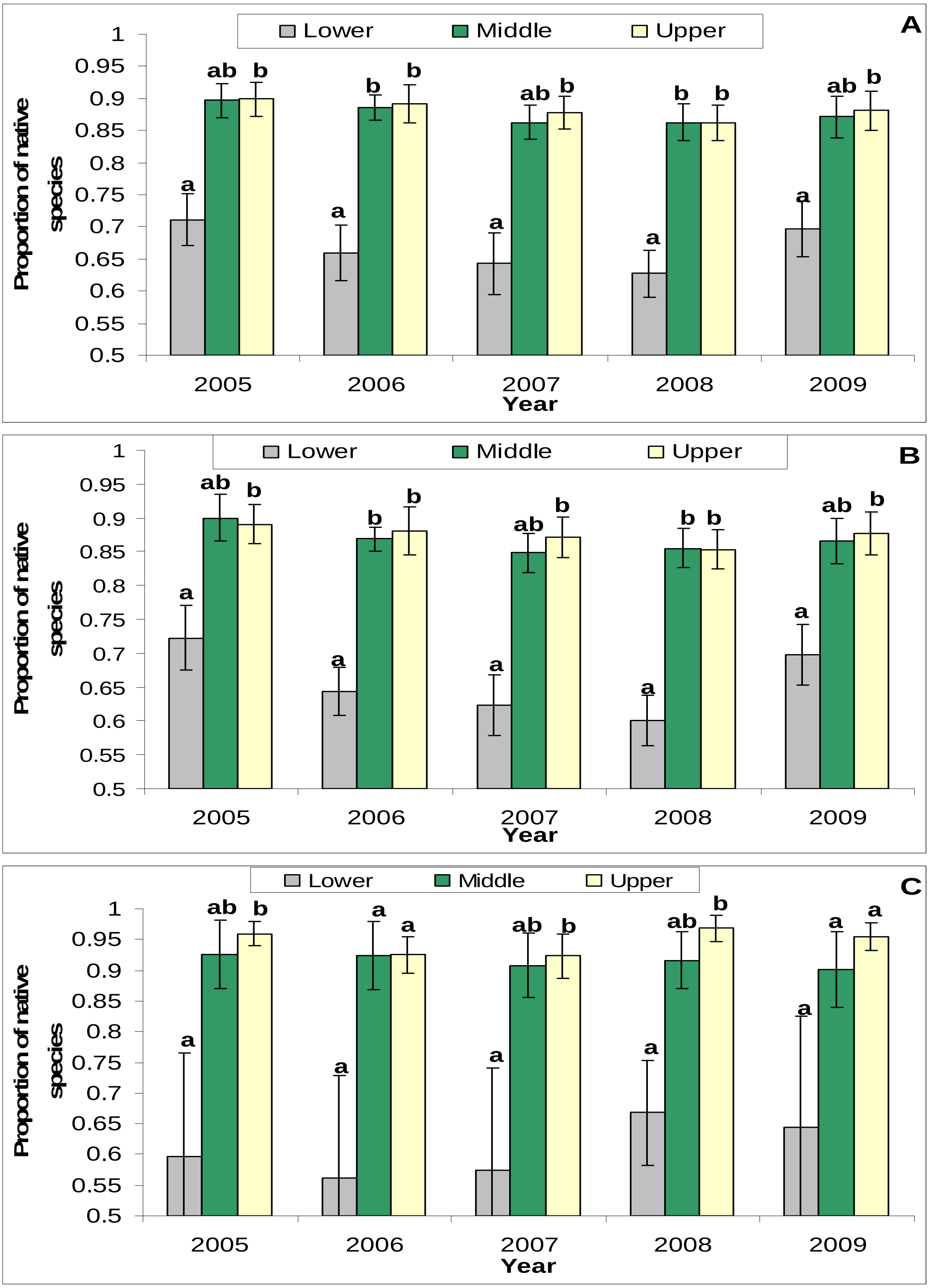


Figure 23. Kruskal-Wallis analysis of mean proportion of native species across sites within each physiographic zone for combined vegetation (A), ground vegetation (B) and regeneration (C). Within years, bars with different letters indicate a significant difference according to post-hoc analyses (p<0.05). Error bars indicate +/- SE.

It is not surprising that the Lower zone contained a lower proportion of native species. Disturbances caused by urban development are expected to extirpate native species while simultaneously promoting the establishment of non-native species that tend to persist in disturbed environments (McKinney 2006). The Lower zone is comprised of nearly four times more urban land cover than the Upper and Middle watersheds. In the Lower watershed, nearly 60% of the land has been converted to urban cover, while only 8% is occupied by natural cover (woodlands and wetlands) (Fig. 24). The lack of differences between the Upper and Middle watershed are also reflected in the land cover of those zones. Both the Upper and Middle zones have only 15% urban cover, while the percent cover of natural, agricultural and successional land uses are similar between the two zones (Fig. 24).

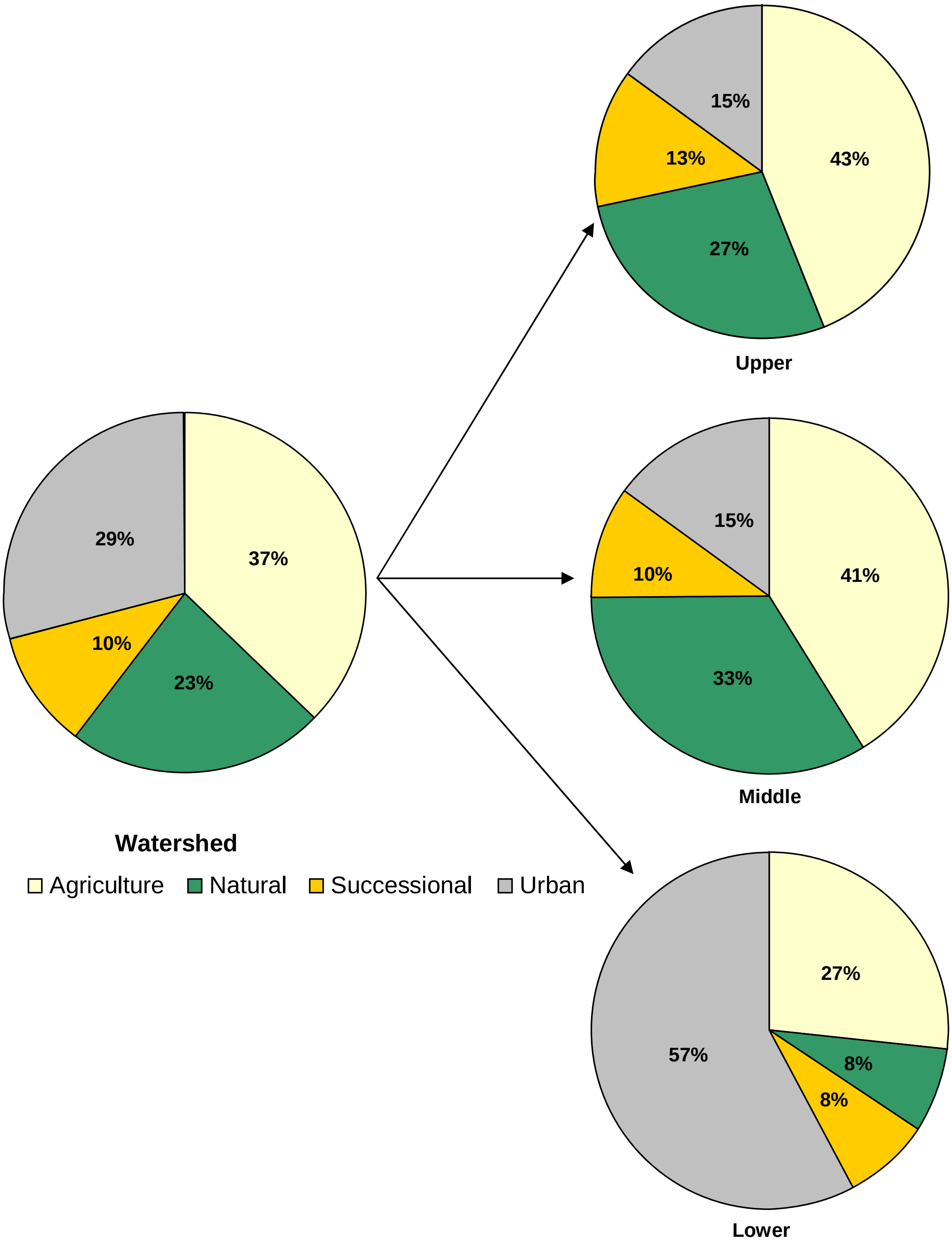


Figure 24. Land cover in the Credit River Watershed (Credit Valley Conservation 2007a).

3.3.3 Species Diversity

Monitoring Question: Did total or native species diversity differ among physiographic zones?

- No differences were observed among zones for all diversity parameters.

No significant differences were detected among zones for total and native ground vegetation (*F*=2.831, *p*=0.091; *F*=3.665, *p*=0.051; Fig. 25) according to repeated measure ANOVA analyses. Similarly, the Kruskal-Wallis test revealed no differences among zones for regeneration diversity (2005, *F*=4.705, *p*=0.095; 2006, *F*=4.509, *p*=0.105; 2007, *F*=4.509, *p*=0.105; 2008, *F*=4.972, *p*=0.083; Fig. 26). This is consistent with spatial differences observed in the species richness analyses. The diversity calculation is partially based on number of species; therefore, parallels are expected between the two types of parameters.

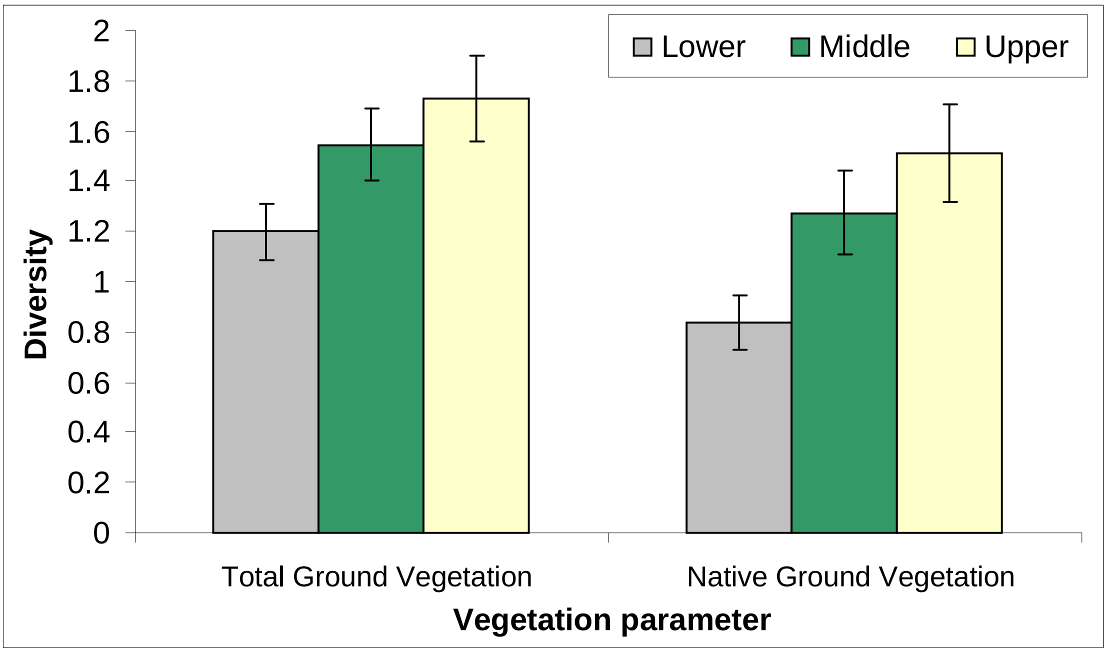


Figure 25. Mean total and native ground vegetation diversity across sites within each physiographic zone in the Credit River Watershed. Repeated measures ANOVA was used for both parameters. Within years, bars with different letters indicate a significant difference according to Tukey's HSD test for unequal sample sizes analyses (*p*<0.05). Error bars indicate +/- SE.

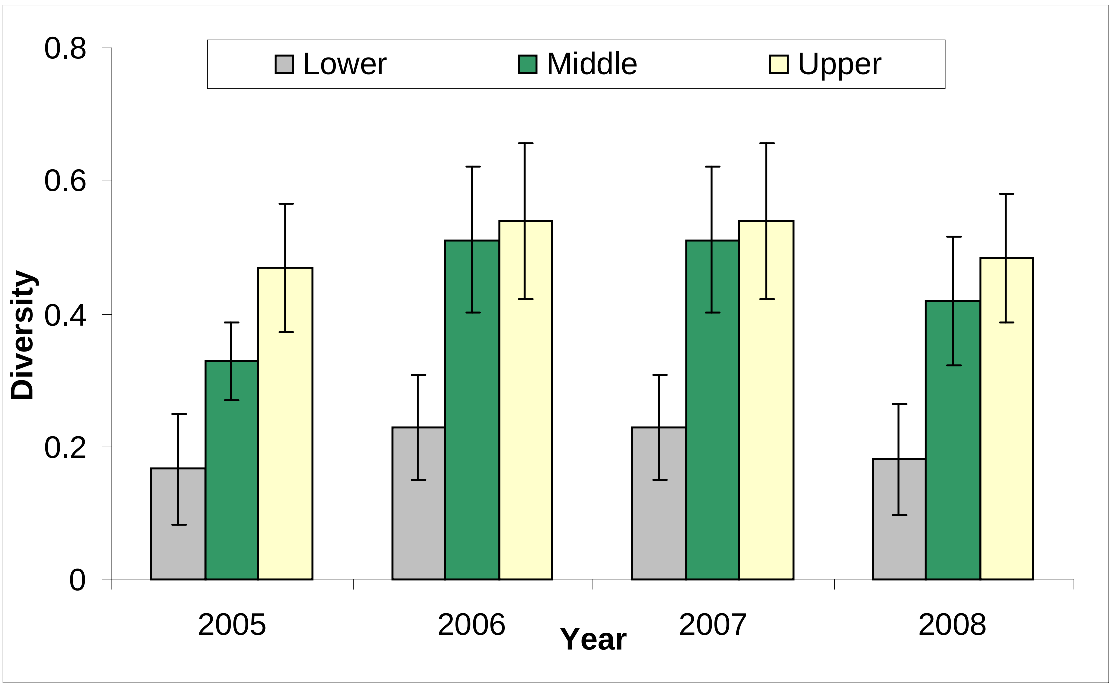


Figure 26. Kruskal-Wallis analysis of mean regeneration diversity across sites within each physiographic zone in the Credit River Watershed. Within years, bars with different letters indicate a significant difference according to post-hoc analyses (p<0.05). Error bars indicate +/- SE.

3.3.4 Species Evenness

Monitoring Question: Did total or native species evenness differ among physiographic zones?

- Generally there were few differences in evenness among the zones, with the lowest evenness in the Upper zone in early years.

There were generally few significant differences observed in evenness for combined and ground vegetation and regeneration (Fig. 27A & B) according to Kruskal-Wallis analyses. Exceptions include that the Upper zone had lower evenness in 2005 for both combined and ground vegetation and in 2005 and 2006 for regeneration (Fig. 27C). Although not significant, the Lower zone tended to have the highest evenness in ground vegetation and regeneration, which may indicate that in urbanized areas of the watershed there are a few dominant species.

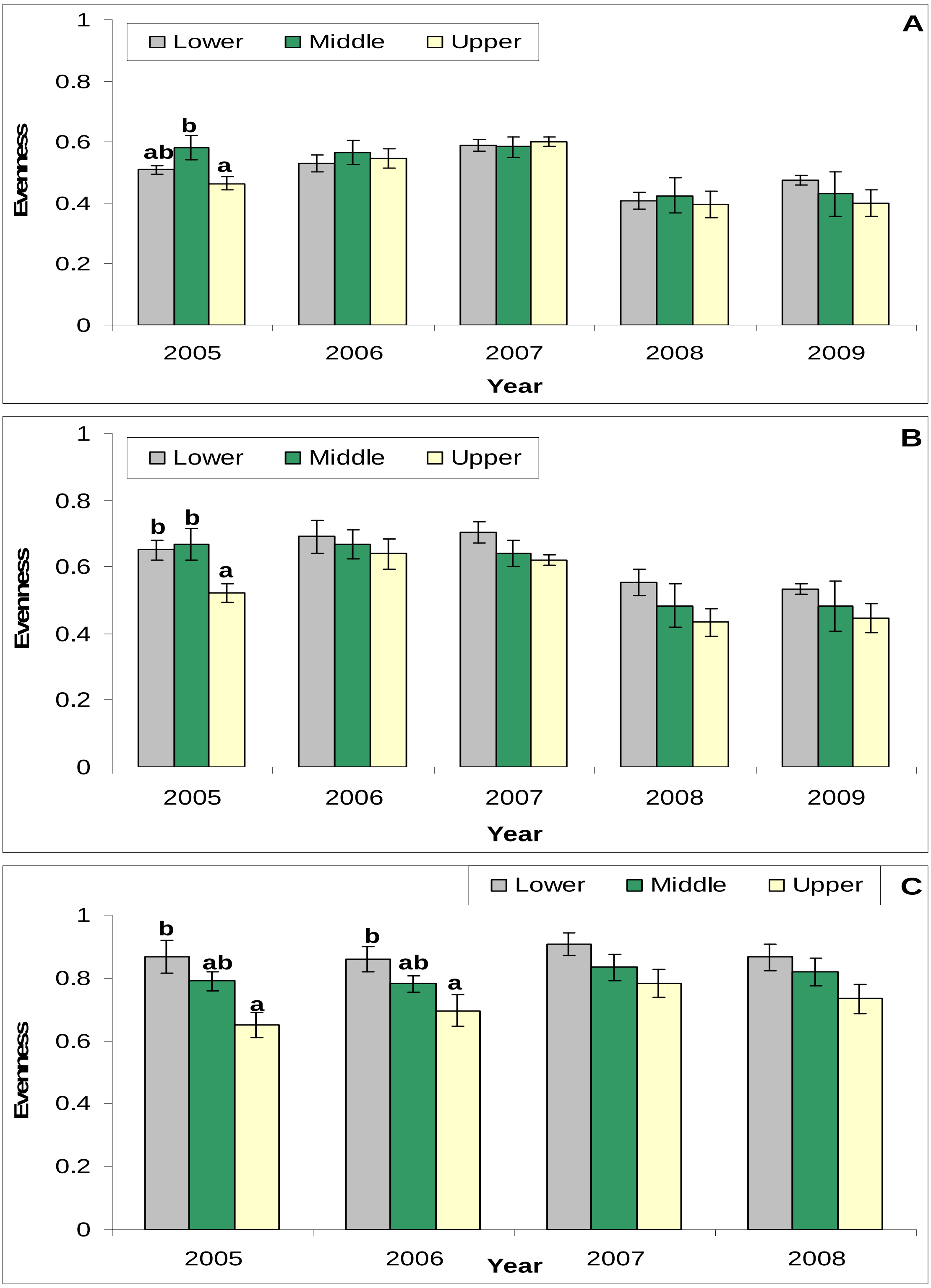


Figure 27. Kruskal-Wallis analysis of mean evenness across sites within each physiographic zone for combined vegetation (A), ground vegetation (B) and regeneration (C). Within years, bars with different letters indicate a significant difference according to post-hoc analyses (p<0.05). Error bars indicate +/- SE.

3.3.5 Coefficient of Conservatism

Monitoring Questions: Did the mCC differ among physiographic zones? Did the number of species with a Conservatism score of 8-10 differ among physiographic zones? Did FQI differ among physiographic zones?

- The mCC and CC 8-10 did not differ among zones.
- FQI was significantly, or nearly so, lower in the Lower zone than the Middle and/or Upper zones in 3 of 5 years.

There was no difference in mCC scores among physiographic zones in the Credit River Watershed (F=1.689, p=0.218; Table 19). Despite the fact that significant differences were not observed, the Lower zone contained the lowest mean mCC and the Upper zone contained the highest mean mCC (Fig. 28). Additionally, there was no difference in the number of individuals with high conservatism scores (CC 8-10) among the physiographic zones in any year (2005, H=0.823, p=0.663; 2006, H =1.394, p=0.498; 2007, H =0.135, p=0.935; 2008, H =0.823, p=0.663; 2009, H =2.062, p=0.357; Fig. 29). Although not significant, a greater number of species with high conservatism scores were observed in the Upper watershed than the Lower and Middle watershed (Fig. 29). However, this is due to the inclusion of Caledon Lake. In three of five years, FQI scores varied significantly among physiographic zones (2005, F=3.983, p=0.041; 2006, F =4.527, p=0.029; 2007, F =3.327, p=0.064; 2008, F =5.245, p=0.019; 2009, F =2.588, p=0.108; Fig. 30). However, in all years except 2008, the post-hoc analysis found no differences among zones. Generally, the Upper and/or Middle watersheds had significantly, or nearly so, higher FQI values than the Lower watershed (Fig. 30). This indicates that FQI may be impacted by urbanization in the Lower zone.

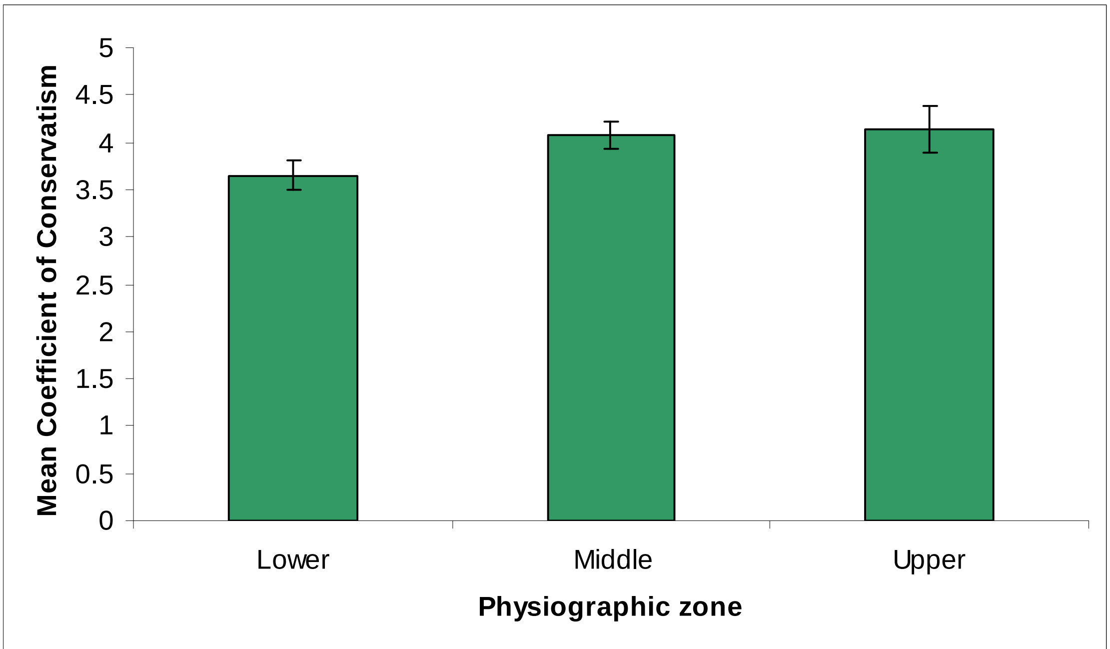


Figure 28. Mean mCC across sites within each physiographic zone throughout the Credit River Watershed. Error bars indicate +/- SE.

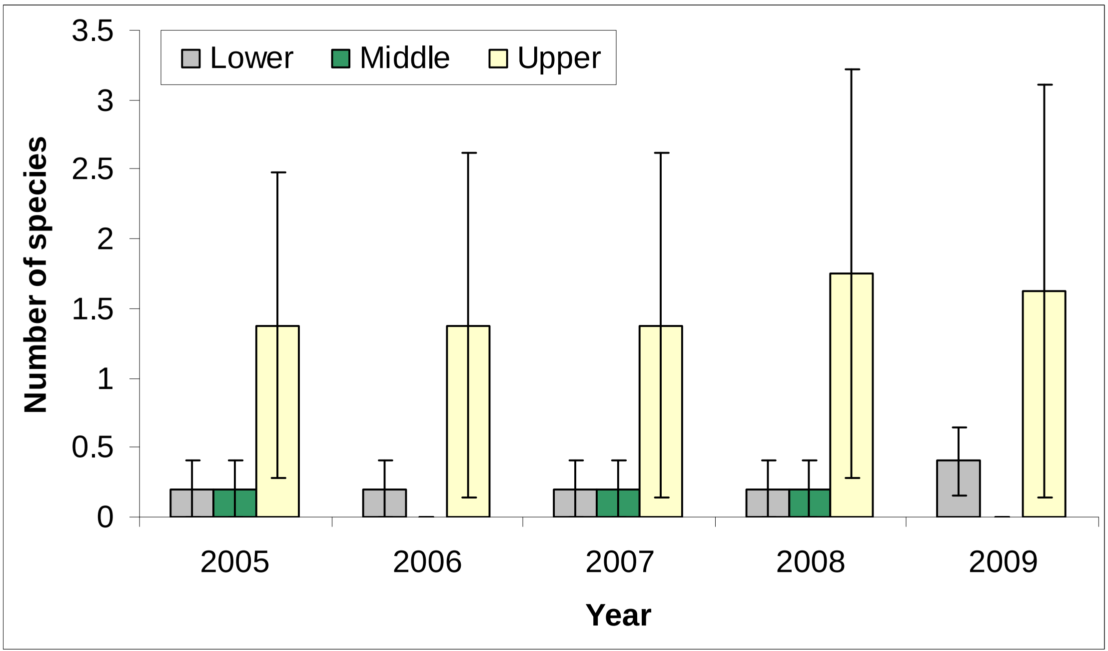


Figure 29. Mean number of species with high conservatism scores (CC 8-10) across sites within each physiographic zone within the Credit River Watershed. Error bars indicate +/- SE.

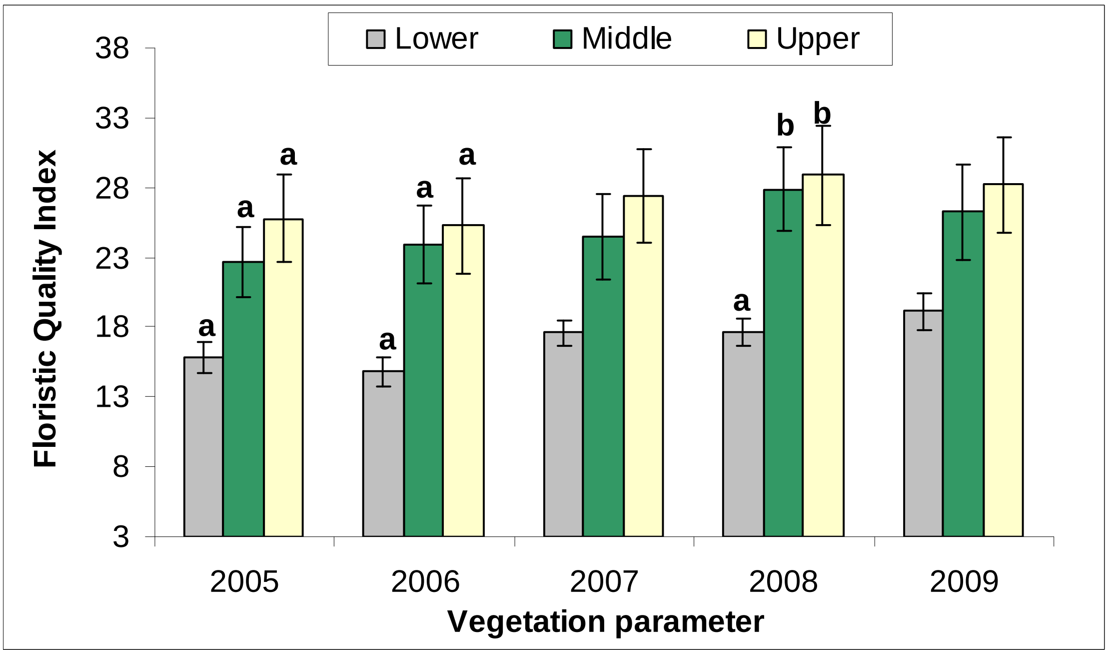


Figure 30. Mean Floristic Quality Index (FQI) across sites within each physiographic zone throughout the Credit River Watershed. Bars with different letters indicate a significant difference according to post-hoc analyses (p<0.05). If no letters are present the ANOVA analysis detected no differences. Error bars indicate +/- SE.

3.3.6 Rare Species

Monitoring Question: Did the number of locally and regionally rare species differ among physiographic zones?

- The number of locally and regionally rare species were unaffected by physiographic zone.

No differences were detected in the number of locally and regionally rare species among physiographic zones, in any year, as indicated by Kruskal-Wallis analyses (Table 19). Despite the fact that differences were not significant, the Upper watershed had a larger number of locally and regionally rare species than the other physiographic zones (Fig. 31). The Lower watershed typically had the lowest number of locally rare species, but surprisingly the Middle watershed contained the lowest number of regionally rare species. This was unanticipated. The Middle watershed is expected to contain the most pristine habitats and is under less development pressure than the other two zones due to the Niagara Escarpment and Green Belt legislation. This may be because the majority of sites monitored in the Middle watershed are swamps, while sites monitored in the Lower and Upper watersheds are composed mainly of marsh habitats. Rare species are almost always associated with species rich communities (Bedford et al. 1999) and the majority of swamps monitored in the watershed had below average species richness. The large number of sites with locally and regionally rare species and species with CC values of 8-10 in the Upper watershed is partially due to the inclusion of Caledon Lake Wetland.

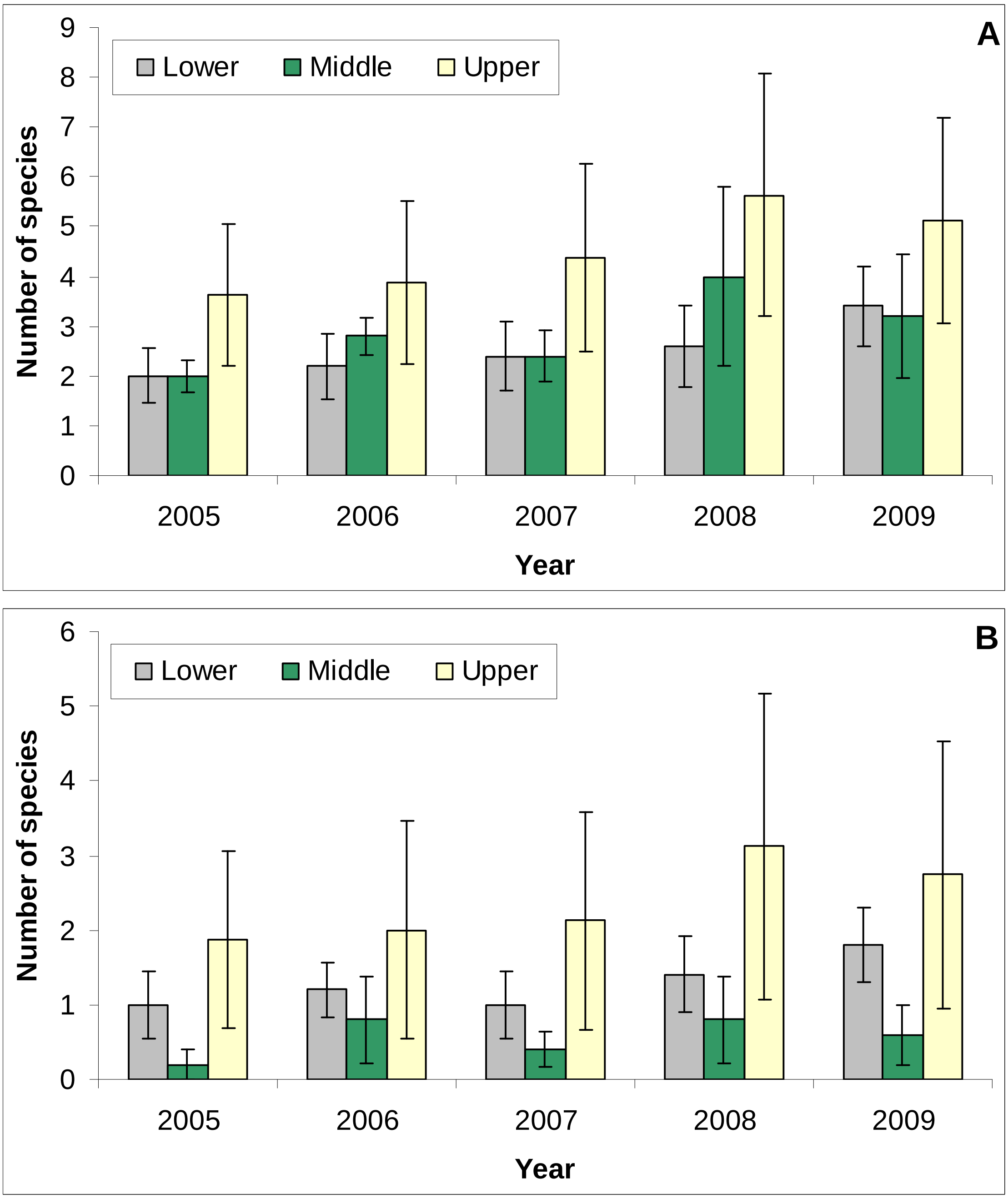


Figure 31. Mean number of locally (A) and regionally (B) rare species across sites within each physiographic zone within the Credit River Watershed. Error bars indicate +/- SE.

3.3.7 Weediness

Monitoring Question: Did weedy species richness differ among physiographic zones? Did the number of species with a weediness score of -3 differ among physiographic zones?

- There was a near significant difference between the Upper and Lower zones for Weedy species richness.
- Weediness count -3 was higher in the Lower zone than the Upper and/or Middle zones.

Spatial analysis with repeated measures ANOVA indicated a significant difference among zones for weedy species richness (F=4.309, p=0.033; Table 19, Fig. 32). However, the Tukey's HSD test only indicated nearly significant differences between the Upper and Lower zones (p=0.054). The Kruskal-Wallis test indicated that the number of individuals with a weediness score of -3 was different among physiographic zones (2005, H=9.379, p=0.009; 2006, H =11.548, p=0.003; 2007, H =10.778, p=0.005; 2008, H =10.490, p=0.005; 2009, H =8.781, p=0.012; Fig. 33). Post-hoc analyses indicated that the Lower watershed contained a significantly greater number of taxa with a weediness score of -3 than the Middle and/or Upper zones. It therefore appears that the number of weedy species and the number of very problematic species are greater in the urbanized Lower zone compared to the Upper and Middle zones, which is consistent with spatial differences in the proportion of native species in the watershed.

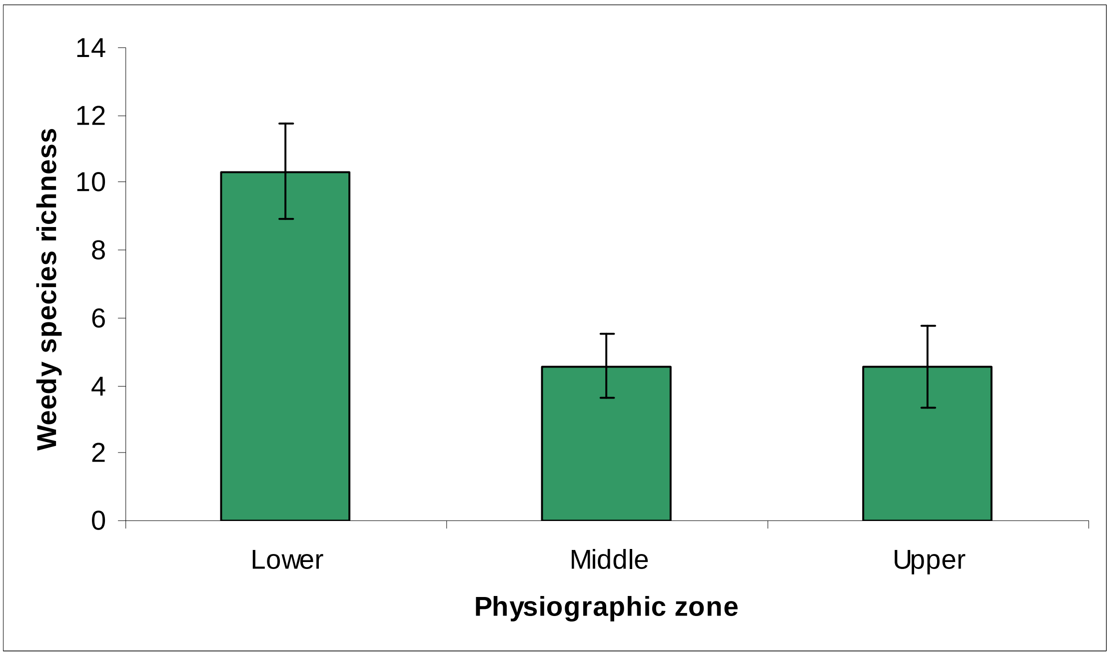


Figure 32. Mean weedy species richness across sites within each physiographic zone throughout the monitoring period in the Credit River Watershed. Error bars indicate +/- SE.

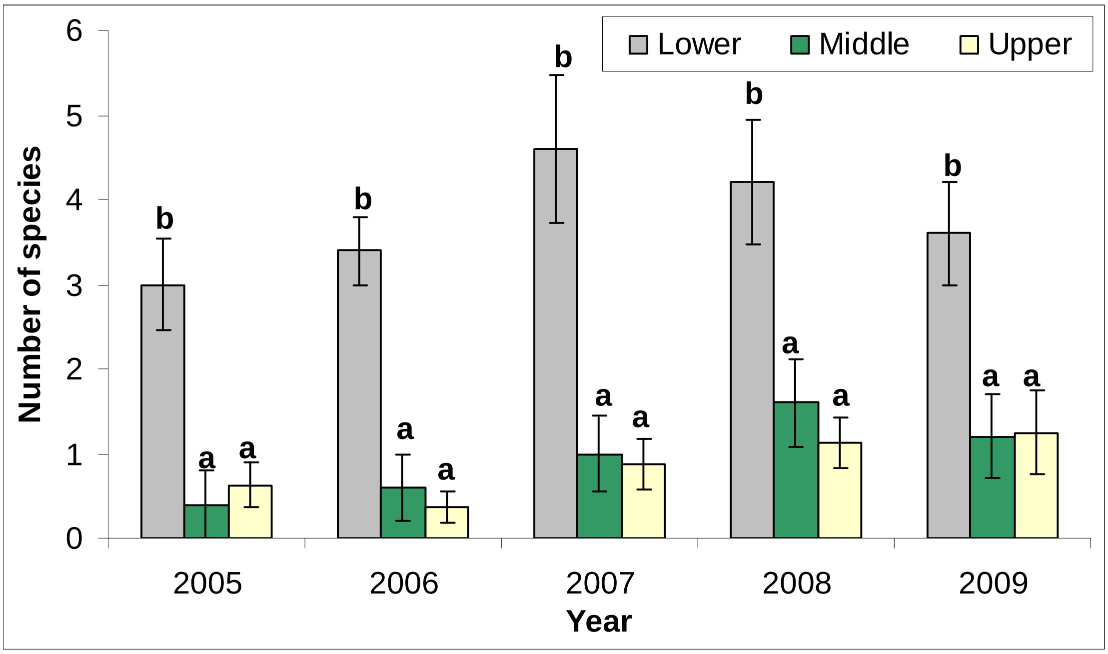


Figure 33. Mean number of species with a weediness score of -3 across sites within each physiographic zone throughout the Credit River Watershed. Within years, bars with different letters indicate a significant difference according to post-hoc analyses (*p*<0.05). Error bars indicate +/- SE.

3.3.8 Power Analysis

For all vegetation parameters analyzed with a Repeated Measures ANOVA analysis, power analysis determined that the following number of sites within the watershed would be needed in order to detect 1, 2 and 3 SD of change: 33, 12 and 9 sites, respectively. Additionally, the following number of sites within each zone would be needed in order to detect 1, 2 and 3 SD of change: 11, 4 and 3 sites, respectively. Therefore, a sufficient number of sites were monitored at both the watershed and physiographic zone scales to detect significant changes in the vegetation parameters with 90% power at an 80% confidence level for effect sizes greater than or equal to 2 SD.

3.4 LANDSCAPE ANALYSIS

3.4.1 Vegetation Parameters

Monitoring Question: Were wetland vegetation parameters correlated with landscape metrics in the Credit River watershed?

- Many parameters indicative of wetland health were positively correlated with habitat patch size, percent natural cover and matrix quality. The majority of the same parameters were negatively correlated with percent urban cover.
- No vegetation parameters were correlated with distance to the nearest road
- Only CC 8-10 was significantly negatively correlated to percent agricultural cover

Spearman rank correlation was used to examine relationships between wetland vegetation and landscape parameters in the Credit River Watershed. Significant correlations must be considered cautiously as they do not imply a cause-and-effect relationship between two parameters, but simply that the parameters are associated with one another (Zar 1999).

The proportion of native species (combined vegetation, ground vegetation and regeneration), native ground vegetation diversity and FQI were all positively correlated with habitat patch size (Table 21). These same parameters were also positively correlated to percent natural cover and matrix quality and negatively correlated to percent urban cover (Table 22). This is in agreement with research showing that fragmentation, leading to smaller wetland sizes, adversely affects both rare and common wetland vegetation species (Hooftman and Diemer 2002). Other research has indicated that the amount of landscape disturbance (combination of agriculture and urbanization) within a 2500 m radius of wetlands is related to a reduction in native graminoid and herbaceous perennial abundance (Galatowitsch et al. 2000). These native perennial species are found to be replaced by annuals or non-native perennials. Therefore, as habitat patch decreases, the amount of landscape disturbance increases and native populations decrease. In addition, weedy species richness and the number of individuals with a weediness score of -3 was negatively correlated to habitat patch size, percent natural cover and matrix quality and positively correlated to percent urban cover. This is consistent with current knowledge that weedy species increase in disturbed habitats (McKinney 2006). These results indicate that urbanization appears to be associated with wetland degradation, as many parameters indicative of healthy wetland vegetation decrease as natural areas become more fragmented.

It was surprising that species richness (combined vegetation and ground vegetation) was not significantly correlated with habitat patch size, percent natural cover and matrix quality. Previous studies have demonstrated a decrease in species richness in association with wetland degradation and an increase in richness with increasing wetland size and surrounding natural cover (Findlay and Houlahan 1997; Lougheed et al. 2008). The lack of association between richness and landscape parameters may be due an increase in non-native species richness in urban areas. However, a positive correlation was seen between matrix quality and regeneration richness.

Table 21. Spearman rank correlations between wetland parameters and habitat patch size and distance to the nearest road.

Vegetation Variable	Habitat Patch Size		Distance to Nearest Road	
	Spearman R	*P* value [a]	Spearman R	*P* value [a]
Combined Vegetation				
Total Species Richness	0.011	0.964	0.059	0.817
Proportion of Native Species Richness	**0.556**	**0.017**	0.350	0.155
Mean Coefficient of Conservatism	0.465	0.052	0.286	0.250
CC 8-10	0.307	0.216	0.086	0.736
Floristic Quality Index	**0.511**	**0.030**	0.216	0.399
Weedy Species Richness	**-0.558**	**0.016**	-0.447	0.063
Weediness Count -3	**-0.805**	**<0.001**	-0.168	0.504
Locally Rare Species	0.134	0.597	0.184	0.464
Regionally Rare Species	-0.072	0.776	0.343	0.164
Ground Vegetation				
Total Species Richness	0.331	0.179	0.142	0.576
Total Species Diversity	0.451	0.060	0.183	0.468
Total Species Evenness	0.082	0.748	-0.049	0.848
Proportion of Native Species Richness	**0.612**	**0.007**	0.387	0.113
Native Species Diversity	**0.472**	**0.048**	0.243	0.332
Native Species Evenness	-0.065	0.798	-0.170	0.499
Regeneration				
Total Species Richness	0.152	0.547	-0.058	0.819
Total Species Diversity	0.267	0.284	0.131	0.604
Total Species Evenness	-0.144	0.570	0.144	0.570
Proportion of Native Species Richness	**0.483**	**0.042**	0.137	0.589

[a] Results significant when $p<0.05$; significant values highlighted in bold.

Table 22. Spearman rank correlations between wetland parameters and selected landscape metrics.

Vegetation Variable	% Agriculture		% Natural		% Urban		Matrix Quality	
	Spearman R	*P* value [a]	Spearman R	*P* value [a]	Spearman R	*P* value [a]	Spearman R	*P* value [a]
Combined Vegetation								
Total Species Richness	0.256	0.305	0.089	0.699	-0.049	0.848	0.133	0.599
Proportion of Native Species	0.385	0.114	**0.622**	**0.006**	**-0.551**	**0.018**	**0.664**	**0.003**
mCC	-0.058	0.820	**0.496**	**0.036**	0.046	0.851	0.408	0.093
CC 8-10	**-0.508**	**0.031**	0.401	0.099	-0.207	0.896	0.327	0.185
Floristic Quality Index	0.263	0.291	**0.476**	**0.046**	**-0.483**	**0.043**	**0.560**	**0.016**
Weedy Species Richness	-0.297	0.232	**-0.645**	**0.004**	0.457	0.057	**-0.581**	**0.011**
Weediness Count -3	-0.263	0.291	**-0.756**	**<0.001**	**0.651**	**0.003**	**-0.758**	**<0.001**
Locally Rare Species	-0.230	0.360	0.007	0.977	0.037	0.883	0.014	0.958
Regionally Rare Species	-0.051	0.842	-0.232	0.355	0.122	0.630	-0.171	0.497
Ground Vegetation								
Total Species Richness	0.146	0.563	0.191	0.448	-0.302	0.224	0.306	0.217
Total Species Diversity	0.151	0.550	0.325	0.188	-0.293	0.239	0.395	0.105
Total Species Evenness	-0.127	0.615	0.271	0.276	-0.130	0.607	0.284	0.254
Proportion of Native Species	0.395	0.105	**0.618**	**0.006**	**-0.577**	**0.012**	**0.666**	**0.003**
Native Species Diversity	0.239	0.340	0.366	0.135	-0.386	0.114	0.459	0.055
Native Species Evenness	-0.315	0.203	0.073	0.773	0.072	0.775	0.055	0.829
Regeneration								
Total Species Richness	0.237	0.344	0.430	0.075	**-0.469**	**0.050**	**0.547**	**0.019**
Total Species Diversity	0.309	0.212	0.424	0.079	-0.317	0.120	0.445	0.064
Total Species Evenness	-0.051	0.842	**-0.606**	**0.008**	0.401	0.099	**-0.577**	**0.012**
Proportion of Native Species	0.220	0.380	**0.543**	**0.020**	-0.439	0.069	**0.529**	**0.024**

[a] Results significant when $p<0.05$; significant values highlighted in bold.

Local biodiversity may be negatively affected by roads through obstructing migration between local populations, altering wetland hydrology and siltation, increasing edge effects in habitat patches, facilitating the invasion of exotic species and increasing human access to wetlands (Findlay and Houlahan 1997). None of the studied vegetation parameters were correlated with the distance to the nearest road (Table 21). Although research has shown that the density of paved roads within 1 to 2 km of a wetland is negatively correlated with vegetative species richness (Findlay and Houlahan 1997), relationships may not have been noted in this study as the density of surrounding roads was not taken into account. The density of roads surrounding the wetland may be more indicative of the effects of roads on wetland species than the distance to a nearby road. For example, Terra Cotta Wetland is situated only 34 m from the nearest road (dirt road); however, it is located in the Middle watershed where natural land cover is more dominant than urban cover and it is located in a natural habitat patch of over 700 ha. In contrast, Meadowvale Wetland is located 155 m from the nearest road (paved city road); it is located in the Lower watershed, where urban land use is more dominant than natural cover, and is located in a natural habitat patch of only 42 ha. Although Terra Cotta is over four times closer to a road than Meadowvale, many parameters indicative of healthy wetland vegetation were consistently higher than Meadowvale. Therefore, distance to the nearest road may not be an effective indicator of the effects of roads on wetland vegetation because it does not account for the type of road and the amount of habitat fragmentation surrounding the monitoring site.

The number of species with a CC value between 8 and 10 was the only parameter found to be significantly correlated to percent agricultural cover (p=0.031, Table 22); this correlation was negative, indicating that as percent agriculture in the surrounding area increases, the number of high CC value species decreases. It is believed that agriculture may cause species loss due to edge effects from herbicide and fertilizer drift, alien plant invasions, and domestic livestock grazing (Galatowitsch et al. 2000). Therefore, these factors may be decreasing the suitability of habitat for highly conservative species.

3.4.2 Species Level Analysis

Monitoring Question: Was there a relationship between selected species and landscape metrics in the Credit River Watershed?

- Garlic Mustard and Common Buckthorn displayed significant negative logistic relationships with habitat patch size.
- None of the selected species displayed a significant relationship with the distance to the nearest road landscape metric.
- Both Purple Loosestrife and Common Buckthorn displayed a significant negative logistic relationship with percent natural cover.
- All three species displayed a significant positive logistic relationship with percent urban cover.

Logistic regression was used to test the relationship between the most weedy species in the watershed – Purple Loosestrife, Garlic Mustard and Common Buckthorn – and the following landscape metrics: habitat patch size, distance to the nearest road, percent natural cover and percent urban cover. There was no significant relationship between the presence of the three species and distance to the nearest road (Purple Loosestrife: X^2= 0.154, p=0.695; Common Buckthorn: X^2= 0.124, p=0.621; Garlic Mustard: X^2= 0.506, p=0.477). Although roads may facilitate the dispersal of invasive non-native species (Forman and Alexander 1998), the lack of relationship between selected species and distance to the nearest road was consistent with the insignificant correlations with vegetation parameters (Table 23). Examining the density of roads surrounding wetlands may provide more meaningful results.

Table 23. Logistic relationship between selected species and landscape metrics.

Species	Landscape Metric	X^2	p-value [a]
Garlic Mustard	Habitat patch size	**9.240**	**0.002**
	Distance to nearest road	0.506	0.477
	Percent natural cover	3.345	0.067
	Percent urban cover	**6.242**	**0.013**
Purple Loosestrife	Habitat patch size	3.347	0.067
	Distance to nearest road	0.154	0.695
	Percent natural cover	**9.377**	**0.002**
	Percent urban cover	**12.259**	**<0.001**
Common Buckthorn	Habitat patch size	**4.300**	**0.038**
	Distance to nearest road	0.124	0.621
	Percent natural cover	**4.233**	**0.040**
	Percent urban cover	**33.905**	**0.048**

[a] Results significant when p<0.05; significant values highlighted in bold.

Garlic mustard was significantly related to habitat patch size and percent urban cover (X^2= 9.240, p=0.002; X^2= 6.242, p=0.013, respectively; Table 23, Figure 34 & 35), However there was no significant relationship with percent natural cover (X^2= 3.345, p=0.067). It therefore appears that percent urban cover, not natural cover, is more critical to the presence of Garlic Mustard. According to the predicted probability of occurrence from the logistic regression, the probability of Garlic Mustard being found in a wetland plot is very high in small habitat patches, but decreases quickly with habitat patch size. In habitat patches of 5000 m^2 or less, the probability of Garlic Mustard occurring in wetlands is between 50-80% (Fig. 34). In habitat patches of over 25000 m^2 there is less than a 1% probability that Garlic Mustard will be found in wetlands. Similarly, there is less than 10% probability that Garlic Mustard will be present in wetlands with 5% or less urban cover in a 2 km radius, while wetlands situated in areas with greater than 70% urban cover in a 2 km radius have an 80% or greater chance of having Garlic Mustard (Fig. 35). It is important to note that habitat patch size is unequally represented by smaller areas and none of the monitored wetlands have above 80% urban cover in a 2km radius; therefore, extrapolation of occurrence probabilities should be made with caution.

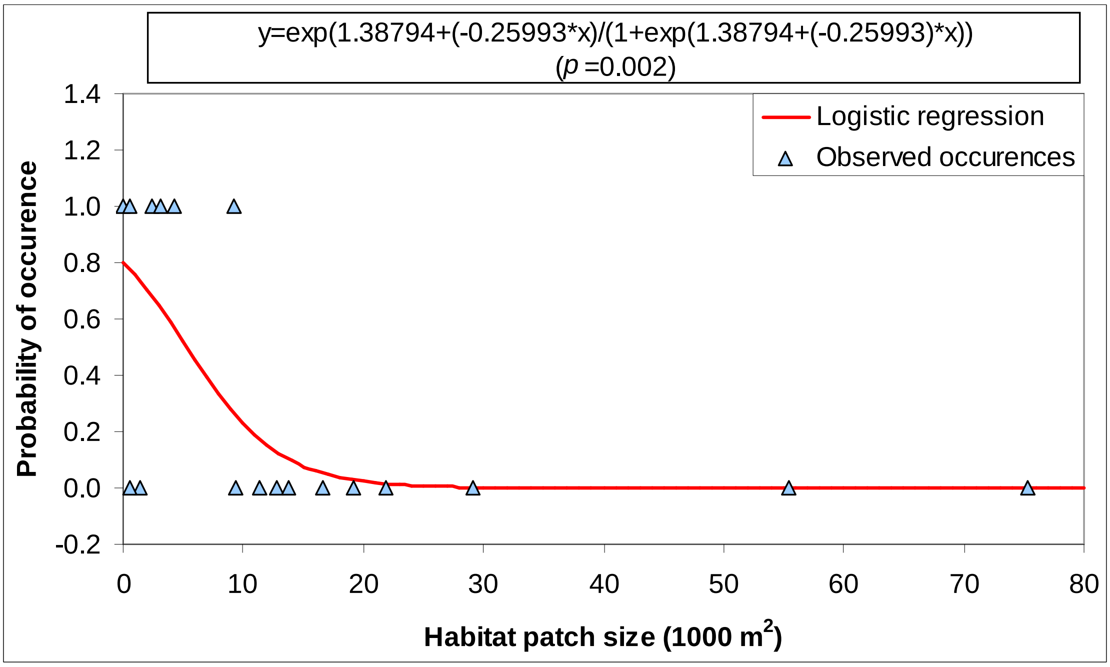


Figure 34. Logistic regression between Garlic Mustard (*Alliaria petiolata*) occurrence at a site and habitat patch size of the site. Equation of the regression line and p-value provided. Logistic regression significant when $p<0.05$.

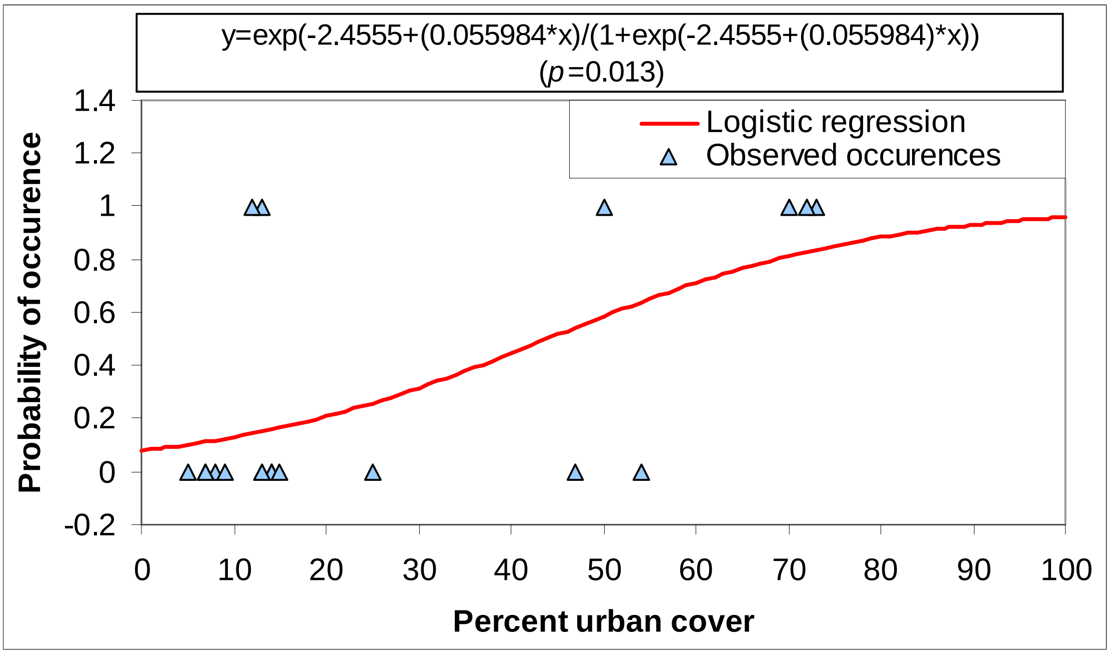


Figure 35. Logistic regression between Garlic Mustard (*Alliaria petiolata*) occurrence at a site and percent urban cover. Equation of the regression line and p-value provided. Logistic regression significant when $p<0.05$.

Although there was no significant relationship between Purple Loosestrife and habitat patch size (X^2= 3.347, p=0.067), Purple Loosestrife did exhibit significant relationships with both percent natural and urban cover (X^2= 9.377, p=0.002; X^2= 12.259, p<0.001, respectively; Table 23, Fig. 36 & 37). The occurrence of Purple Loosestrife at wetland monitoring plots decreased with increasing natural cover and increased with increasing urban cover. Monitoring sites with 50% or greater natural cover in a 2 km radius had less than a 10% probability of Purple Loosestrife being present; conversely, in areas with less than 15% urban cover the probability of occurrence was less than 20%. It appears that both urban and natural cover may be critical for the presence of Purple Loosestrife. This may not have been reflected in the relationship with habitat size because of the amount of agriculture in the area or because not enough site-years were available to detect a significant relationship (Table 23).

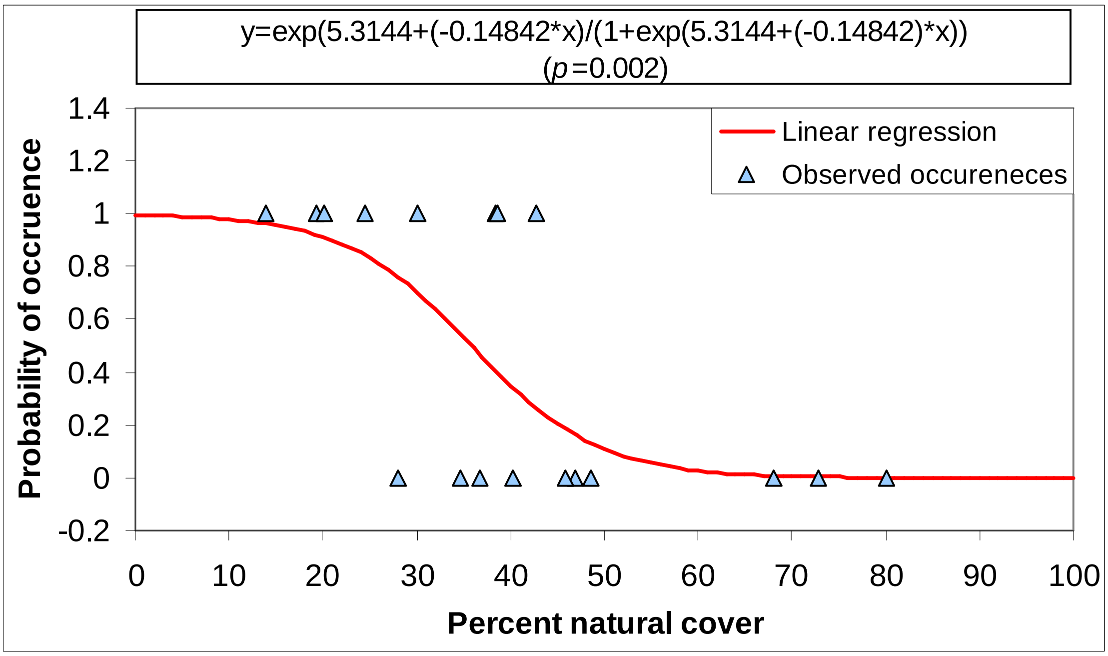


Figure 36. Logistic regression between Purple Loosestrife (*Lythrum salicaria*) occurrence at a site and percent natural cover. Equation of the regression line and p-value provided. Logistic regression significant when p<0.05.

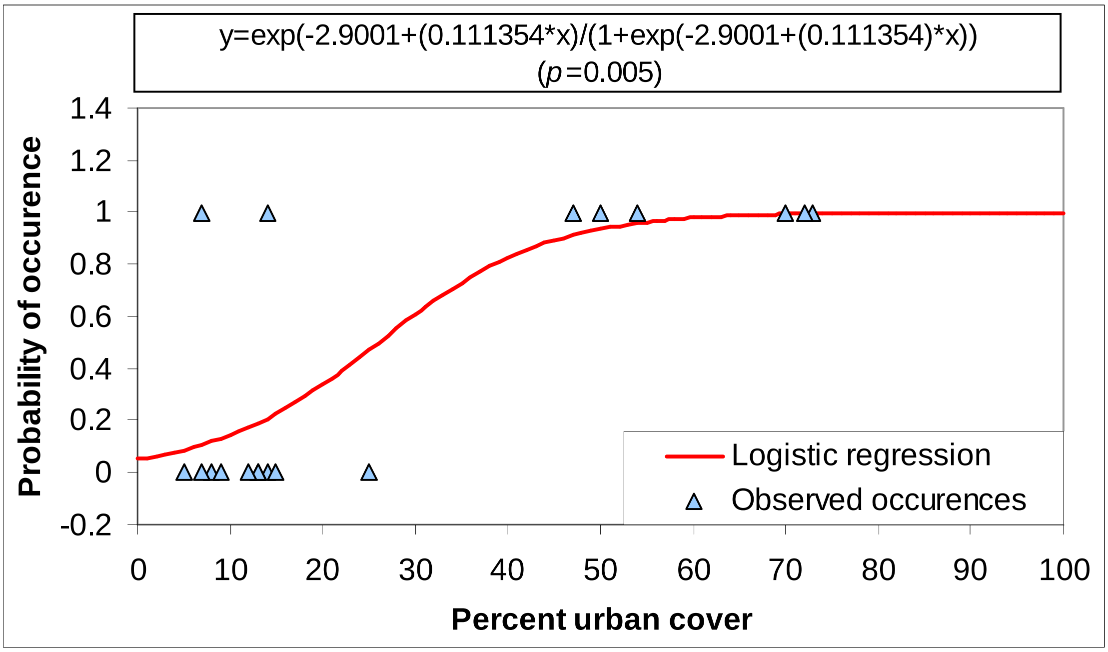


Figure 37. Logistic regression between Purple Loosestrife (*Lythrum salicaria*) occurrence at a site and percent urban cover. Equation of the regression line and p-value provided. Logistic regression significant when $p<0.05$.

Common Buckthorn was related to habitat patch size, percent natural cover and percent urban cover (X^2= 4.300, p=0.038; X^2= 4.233, p=0.040; X^2= 33.905, p=0.048, respectively; Fig. 38-40). In wetlands with greater than 70% natural cover in a 2 km radius, there was less than 5% probability of the occurrence of Common Buckthorn. Similarly, wetlands with greater than 15% urban cover in a 2 km radius had greater than 20% probability of the occurrence of Common Buckthorn and wetlands in a habitat patch of greater than 1000 m^2 had less than a 50% probability of the occurrence of Common Buckthorn.

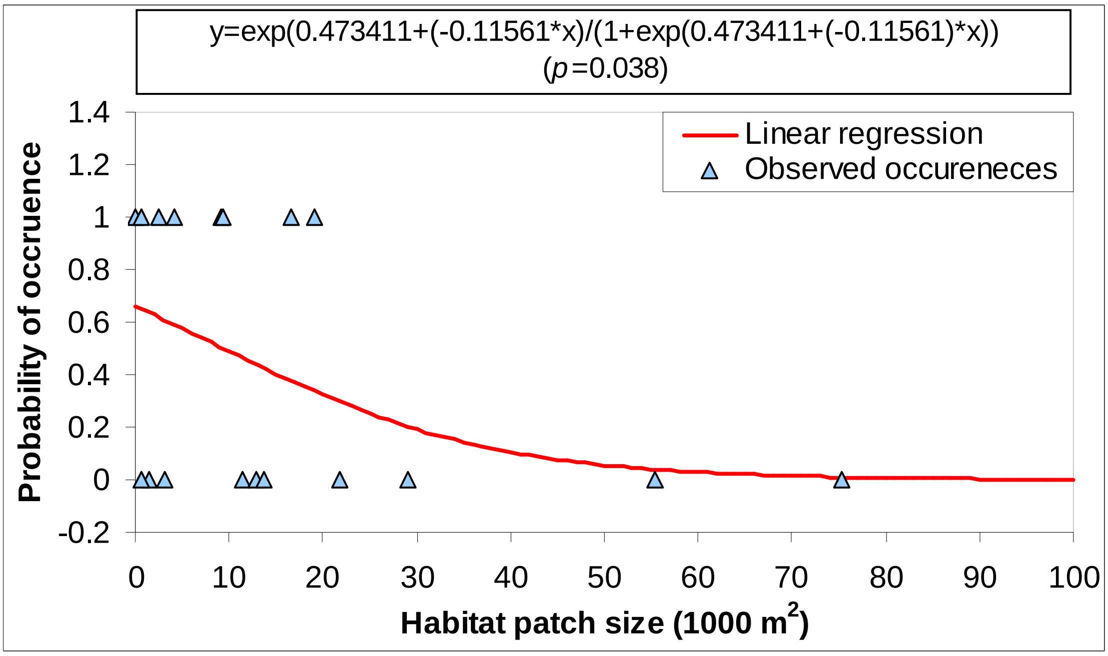


Figure 38. Logistic regression between Common Buckthorn (*Rhamnus cathartica*) occurrence at a site and habitat patch size. Equation of the regression line and p-value provided. Logistic regression significant when $p<0.05$.

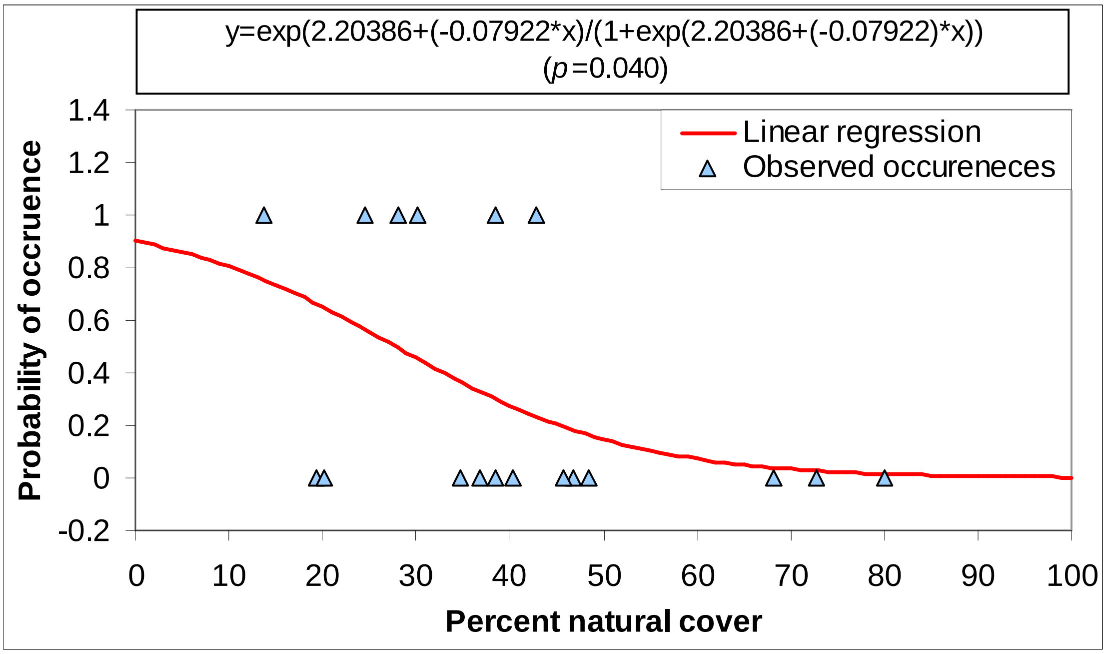


Figure 39. Logistic regression between Common Buckthorn (*Rhamnus cathartica*) occurrence at a site and percent natural cover. Equation of the regression line and p-value provided. Logistic regression significant when $p<0.05$.

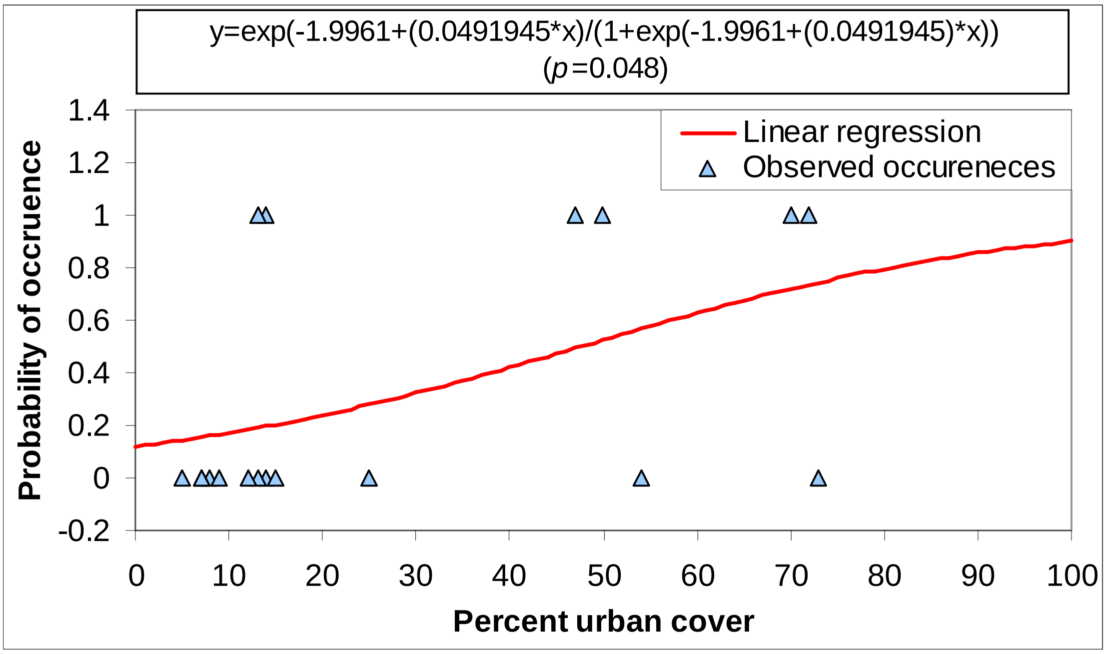


Figure 40. Logistic regression between Common Buckthorn (*Rhamnus cathartica*) occurrence at a site and percent urban cover. Equation of the regression line and p-value provided. Logistic regression significant when $p<0.05$.

3.4.3 Power Analysis

Table 24 lists the calculated number of monitoring sites required to determine a significant logistic relationship between the presence of the selected species and the landscape metrics. Analysis could not be performed for percent urban cover because of its bimodal distribution that could not be normalized. For relationships between Purple Loosestrife and Common Buckthorn and percent natural cover data quality was green. This indicates that there were sufficient site-years to detect a legitimate logistic regression between these species and percent natural cover. Although data quality for relationships between Garlic Mustard and percent natural cover was considered red, the current number of monitored wetland sites (18) is very close to N (19); and therefore, data quality may improve with additional years of data. For relationships between all three selected species and distance to the nearest road data quality was red. This indicates that there were insufficient site-years to detect a legitimate logistic regression. There were sufficient site-years to detect a legitimate regression between Garlic Mustard and habitat patch size; however this was not the case for Purple loosestrife and Common Buckthorn.

Table 24. The calculated number of monitoring sites (N) required to determine a significant logistic relationship between selected species and landscape metrics.

Species	Landscape Metric [a]	N	Data Quality
Garlic Mustard	Habitat patch size	9	Green
	Distance to nearest road	346	Red
	Percent natural cover	19	Red
	Percent urban cover	N/A	N/A
Purple Loosestrife	Habitat patch size	23	Red
	Distance to nearest road	3038	Red
	Percent natural cover	4	Green
	Percent urban cover	N/A	N/A
Common Buckthorn	Habitat patch size	21	Red
	Distance to nearest road	1670	Red
	Percent natural cover	15	Green
	Percent urban cover	N/A	N/A

[a] Landscape metrics were square root transformed for power analysis; analysis could not be performed for percent urban cover because of its bimodal distribution that could not be normalized.

4.0 CONCLUSIONS

Several wetland vegetation parameters were stable in the Credit River Watershed between 2005 and 2009. Although species richness and diversity were found to be increasing, these trends may be attributed to improved monitoring quality. As the monitoring program continues, it is expected that this bias will stabilize and it will be possible to detect biological changes in richness and diversity over time. Other wetland vegetation parameters including: mCC, FQI, weediness score -3, wetness, the number of locally and regionally rare species and CC 8-10, were either stable or fluctuated among years, but did not display an increasing or decreasing trend. Yearly fluctuations are to be expected, as weather and water levels vary over time (Wilcox et al. 2002; Touchette et al. 2008). It is interesting to note that the proportion of native species decreased and weedy species richness increased between 2005 and 2008.

There were also some notable differences among physiographic zones within the Credit River Watershed. The Lower watershed was different than the other physiographic zones for several vegetation parameters. In general, the Lower watershed contained a lower proportion of native species, higher weedy species richness and a greater number of -3 weedy species. These differences reflect the expected changes in vegetation that accompany increasing urbanization (McKinney 2006) and support the need for the current invasive species management program at CVC. The Middle and Upper watershed were not significantly different for any of the vegetation parameters examined.

Currently, wetland community types are not evenly distributed among physiographic zones. Monitoring sites consist of five marsh habitats in the Lower watershed, one marsh and four swamp habitats in the Middle watershed, and two swamps and six marsh habitats in the Upper watershed. Increasing the number of sites to include an equal distribution of marsh and swamp habitats will improve the program’s ability to detect spatial differences within the watershed.

Many of the parameters indicative of healthy wetland vegetation were significantly positively correlated with habitat patch size, percent natural cover and matrix quality. The majority of the same parameters were negatively correlated with percent urban cover. This indicated that as urbanization increases and habitat patch size and percent natural cover decreases, wetlands in the Credit River Watershed may be becoming more degraded. Parameters which are correlated with landscape metrics may be considered good monitoring variables, as they may be sensitive to anthropogenic disturbance (Noss 1999). Special attention should be paid to these vegetation parameters in the future, as increasing or decreasing trends may be an early warning sign for ecosystem degradation. All three selected species, highly invasive non-natives at wetland sites, showed some combination of significant positive relationships with percent urban cover or significant negative relationships with percent natural cover and/or habitat patch size. None of the studied vegetation parameters or species of interest displayed a significant relationship with the distance to the nearest road landscape metric. Road density may be a more appropriate metric for capturing the fragmenting effects of roads.

Overall, changes in wetland vegetation parameters between 2005 and 2009 in the Credit River Watershed appear to be linked to urbanization, and are most prominent in the Lower watershed. Deterioration of wetlands has the potential to become more severe as urbanization increases. This of concern, as a large proportion of wetlands in the watershed have already been altered or lost.

5.0 FUTURE DIRECTIONS

Several improvements and changes to the Terrestrial Monitoring Program are currently being evaluated, which will assist in future data collection and interpretation of results. Ecological Land Classification of all sites will be completed during the summer of 2010. These designations will provide insight to the effect of ecological classification on vegetation in the Credit River Watershed and assist the interpretation of temporal and spatial results. In addition, the Terrestrial Monitoring Program is examining the application of panel design to minimize the impact of monitoring on vegetation plots.

At the data analysis stage, several additional analyses will be explored that were beyond the scope of the five year review. Additional methods recommended by external reviewers (Bohdan Kowalyk, pers. comm.; Emily Gonzales, pers. comm.) will be evaluated, including generalized linear models and Bayesian analyses (Wade 2000) to examine vegetation trends over time. Several other metrics may be incorporated into the analyses as covariates, including: surveyor variation, soil moisture and pH, and canopy closure. In addition, vegetation parameters will be compared to other biotic and abiotic parameters such as soil chemistry and pH, birds and salamanders within forest communities. The possibility of monitoring wetland area will also be considered to determine if wetland area or wetland/terrestrial land boundaries are changing over the study period. A wetland hydrological monitoring program is also currently being developed, which will assist in drawing conclusions between vegetation changes and urbanization as well as other land use changes and climate change (Credit Valley Conservation 2010b).

Also, thresholds will be established for each monitoring parameter when at least five years of stable baseline data exists. Currently the Terrestrial Monitoring Program is developing a strategy for management actions to be undertaken when an indicator (or a suite of indicators) surpasses their established threshold, indicating a decline in the overall integrity of the Credit River Watershed. It should be noted that the baselines and thresholds presented in this report are preliminary in nature. The five year baseline period used to calculate indicator thresholds is based on the maximum number of years of reliable data currently available to the monitoring program. These current data represent the best available steady state information. Though indicators may naturally vary above and below these baselines over longer timeframes, we do not currently possess this information. Long term data may reveal additional patterns, such as wider than expected variability or cyclic behaviour oscillating over multiple years. As a result, established baselines and thresholds must be reviewed as additional monitoring data becomes available. To this end, a complete review of all indicator baselines and thresholds will be conducted at the 10 year point of the program.

The limitations of current baselines and thresholds should also be considered in the context of overall monitoring program design. This is because power analysis, a statistical assessment tool that can help inform decisions concerning program design, incorporates values associated with the identified baselines. This reliance on preliminary baselines, combined with the idiosyncrasies associated with individual power analysis techniques and the highly assimilative nature of most ecological indicators, preclude us from making program design decisions based solely on assessment of power. For instance, indicators with low abundance or high natural variability are more likely to provide data of lower power. Even if tests reveal a lack of power in the current program configuration, the data may still be providing valuable information. This is particularly the case when results from all monitoring questions are assessed in an integrated fashion. Hence, program design should be steered by a combination of power analysis, logistic considerations, and integrated ecological knowledge.

Finally, developing a management actions strategy will ensure that detrimental ecosystems changes observed by the Terrestrial Monitoring Program can be mitigated. Through this mitigation the Terrestrial Monitoring Program will assist CVC in achieving its corporate vision of “an environmentally healthy Credit River Watershed for present and future generations.”

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APPENDIX A: WETLAND MONITORING SITES

Table 1. Wetland Health Monitoring Sites established throughout the Credit River Watershed.

Site #	Site Name	Official Evaluated Wetland Name [b]	Township	County	Wetland Type	Physiographic zone	PSW, ESA and/or ANSI Designation [a]	Habitat patch size (ha)
W-01	Rattray Marsh Wetland	Rattray Marsh Wetland Complex	Mississauga	Regional Municipality of Peel	Marsh	Lower	PSW, ESA, ANSI	92.27
W-02	Credit River Wetland	Credit River Marshes Wetland Complex	Mississauga	Regional Municipality of Peel	Marsh	Lower	ESA, ANSI	0.26
W-03	Creditview Wetland	Creditview Wetland	Mississauga	Regional Municipality of Peel	Marsh	Lower	PSW, ANSI	5.38
W-04	Meadowvale Wetland	Churchville-Norval Wetland Complex	Mississauga	Regional Municipality of Peel	Marsh	Lower	ESA	42.29
W-12	Winston Churchill Wetland	Levi's Creek Wetland Complex	Halton Hills	Regional Municipality of Peel	Marsh	Lower		114.06
W-06	Hungry Hollow Wetland	Hungry Hollow Wetland	Halton Hills	Regional Municipality of Peel	Swamp	Middle	PSW, ESA	127.86
W-07	Acton Wetland	Acton - Silver Creek Wetland Complex	Halton Hills	Regional Municipality of Peel	Swamp	Middle	PSW, ESA	753.26
W-08	Terra Cotta Wetland	Caledon Lake Wetland Complex	Caledon	Regional Municipality of Peel	Swamp	Middle	ESA, ANSI	165.92
W-09	Ken Whillans Wetland	N/A	Caledon	Regional Municipality of Peel	Swamp	Middle		191.18
W-10	Warwick Wetland	Little Credit River Wetland Complex	Caledon	Regional Municipality of Peel	Marsh	Middle	PSW, ESA, ANSI	93.12
W-11	Erin Pine Estates Wetland	West Credit River	Erin	Wellington County	Marsh	Upper	PSW	24.66
W-13	Hillsburgh Wetland	Alton-Hillsburgh Wetland Complex	Erin	Wellington County	Marsh	Upper	PSW, ESA	14.37
W-15	Grange Orpen Wetland	Credit River at Alton Wetland Complex	Caledon	Regional Municipality of Peel	Swamp	Upper	PSW, ESA	137.59
W-16	Starr Wetland	Star Wetland Complex	Caledon	Regional Municipality of Peel	Marsh	Upper		291.34
W-17	Speersville Wetland	Speersville Wetland Complex	Caledon	Regional Municipality of Peel	Marsh	Upper	PSW, ESA	218.85
W-18	Caledon Lake Wetland	Caledon Lake Wetland Complex	Caledon	Regional Municipality of Peel	Swamp	Upper	PSW, ESA, ANSI	554.82
W-19	Melville Wetland	Orangeville Wetland Complex (MO3)	Orangeville	County of Dufferin	Marsh	Upper	PSW	5.53
W-20	Belfountain Wetland	N/A	Caledon	Regional Municipality of Peel	Marsh	Upper		30.86

[a] PSW, Provincially Significant Wetland; ESA, Environmentally Sensitive Area; ANSI, Area of Natural and Scientific Interest.
[b] Wetland plot apart of the indicated official evaluated wetland or wetland complex.

APPENDIX B: WETLAND VEGETATION PARAMETERS INCLUDED IN ANALYSIS

Table 1. Wetland vegetation parameters analyzed in the Credit River Watershed.

Vegetation Parameter	Normal Distribution	Data Transformation	Analysis Type [a]
Ground Vegetation			
Species Richness	Yes	No	Parametric
Total Species Diversity	Yes	No	Parametric
Total Species Evenness	N/A	No	Non-parametric
Native Species Diversity	Yes	No	Parametric
Native Species Evenness	N/A	No	Non-parametric
Proportion of Native Species	NA	No	Non-parametric
Regeneration [b]			
Species Richness	N/A	No	Non-parametric
Species Diversity	N/A	No	Non-parametric
Species Evenness	N/A		Non-parametric
Proportion of Native Species	N/A	No	Non-parametric
Combined Vegetation			
Species Richness	Yes	No	Parametric
Proportion of Native Species	N/A	No	Non-parametric
Mean Wetness Index	Yes	No	Parametric
mCC [c]	No	Log	Parametric
FQI [c]	Yes	Log	Parametric
CC 8-10	N/A	No	Non-parametric
Locally Rare	N/A	No	Non-parametric
Regionally Rare	N/A	No	Non-parametric
Weedy Species Richness	Yes	Log	Parametric
Weediness Count -3	N/A	No	Non-parametric

[a] Parametric analyses were Linear Regression to examine trends over time, and Repeated-Measures ANOVA to examine spatial differences between groups. Non-parametric tests were conducted for data which did not meet parametric test assumptions, and included the Friedman Test to examine temporal differences between years, and Kruskal-Wallis to examine differences over time.
[b] All regeneration data were analyzed using non-parametric methods due to spatial autocorrelation between the sites.
[c] mCC, Mean Coefficient of Conservatism; FQI, Floristic Quality Index.

APPENDIX C: RARE AND HIGHLY CONSERVATIVE SPECIES OBSERVED AT WETLAND MONITROING SITES

Table 1. Rare and highly conservative species observed at wetland monitoring sites in the Credit River Watershed.

Latin Name	Common Name	Locally Rare	Regionally Rare	CC Value	Number of Years Detected	Wetland Site
Andromeda polifolia ssp. glaucophylla	Bog Rosemary	X	X	10	5	Caledon Lake Wetland
Apios americana	American Groundnut	X	X	6	4	Credit River Wetland
Betula pumila	Dwarf Birch	X	X	9	4	Caledon Lake Wetland
Bolboschoenus fluviatilis	River Bulrush	X	X	7	4	Rattray Marsh Wetland Credit River Wetland
Campanula aparinoides	Marsh Bellflower	X	X	7	5	Erin Pine Estates Wetland
Cardamine pratensis	Cuckoo Flower	X	X	7	3	Rattray Marsh Wetland Credit River Wetland Erin Pine Estates Wetland
Carex albursina	White Bear Sedge	X		7	4	Credit River Wetland
Carex alopecoidea	Foxtail Sedge	X		6	4	Ken Whillans Wetland
Carex amphibola	Narrowleaf Sedge			9	5	Rattray Marsh Wetland Credit River Wetland
Carex aquatilis	Water Sedge	X	X	7	3	Belfountain Wetland Caledon Lake Wetland Starr Wetland Warwick Wetland
Carex atherodes	Awned Sedge	X	X	6	5	Hungry Hollow Wetland
Carex bromoides	Brome-like Sedge	X	X	7	2	Warwick Wetland
Carex comosa	Bristly Sedge	X		5	5	Creditview Wetland Hungry Hollow Wetland Warwick Wetland Hillsburgh Wetland
Carex flava	Yellow Sedge	X		5	5	Erin Pine Estates Wetland Hillsburgh Wetland
Carex leptalea	Bristly-stalk Sedge			8	5	Caledon Lake Wetland Grange Orpen Wetland Terra Cotta Wetland
Carex magellanica ssp. irrigua	Boreal Bog Sedge	X	X	10	4	Caledon Lake Wetland
Carex utriculata	Northwest Territory Sedge	X		7	5	Melville Wetland Belfountain Wetland

APPENDIX C: RARE AND HIGHLY CONSERVATIVE SPECIES OBSERVED AT WETLAND MONITORING SITES (Cont'd)

Latin Name	Common Name	Locally Rare	Regionally Rare	CC Value	Number of Years Detected	Wetland Site
Carex vesicaria	Inflated Sedge	X	X	7	5	Erin Pine Estates Wetland
Cephalanthus occidentalis	Buttonbush	X	X	7	2	Creditview Wetland
Ceratophyllum demersum	Common Hornwort	X	X	4	5	Acton Wetland Winston Churchill Wetland
Chamaedaphne calyculata	Leatherleaf	X	X	9	4	Caledon Lake Wetland
Cirsium discolor	Field Thistle			9	1	Belfountain Wetland
Cornus amomum ssp. obliqua	Silky Dogwood	X		5	4	Creditview Wetland Rattray Marsh Wetland Ken Whillans Wetland
Cuscuta gronovii	Gronovius Dodder	X		4	5	Credit River Wetland Warwick Wetland
Cypripedium parviflorum var. makasin	Small Yellow Lady's- slipper	X		7	3	Hungry Hollow Wetland
Drosera rotundifolia	Roundleaf Sundew	X	X	7	5	Caledon Lake Wetland
Elymus riparius	River Wild-rye	X	X	7	1	Hungry Hollow Wetland
Epilobium palustre	Marsh Willow-herb			10	2	Erin Pine Estates Wetland Speersville Wetland Caledon Lake Wetland
Galium aparine	Catchweed Bedstraw	X		4	2	Warwick Wetland Rattray Marsh Wetland
Impatiens pallida	Pale Touch-me-not	X		7	3	Meadowvale Wetland
Ledum groenlandicum	Labrador-tea	X	X	9	5	Caledon Lake Wetland
Lemna trisulca	Star Duckweed	X		4	3	Creditview Wetland
Linnaea borealis ssp. longiflora	Twinflower	X		7	3	Caledon Lake Wetland
Liparis loeselii	Loesel's Twayblade	X		5	2	Erin Pine Estates Wetland
Lonicera hirsuta	Hairy Honeysuckle	X	X	7	1	Caledon Lake Wetland
Lonicera oblongifolia	Swamp Fly-honeysuckle	X	X	8	1	Caledon Lake Wetland
Ludwigia palustris	Marsh Seedbox	X	X	5	4	Winston Churchill Wetland Melville Wetland

APPENDIX C: RARE AND HIGHLY CONSERVATIVE SPECIES OBSERVED AT WETLAND MONITORING SITES (Cont'd)

Latin Name	Common Name	Locally Rare	Regionally Rare	CC Value	Number of Years Detected	Wetland Site
Lysimachia thyrsiflora	Water Loosestrife	X		7	5	Hungry Hollow Wetland Warwick Wetland Erin Pine Estates Wetland Grange Orpen Wetland Starr Wetland Caledon Lake Wetland Melville Marsh Belfountain Wetland
Nemopanthus mucronatus	Mountain Holly	X	X	8	5	Caledon Lake Wetland
Orthilia secunda	One-side Wintergreen	X	X	5	4	Caledon Lake Wetland
Picea glauca	White Spruce	X		6	5	Caledon Lake Wetland Warwick Wetland Grange Orpen Wetland
Potentilla palustris	Marsh Cinquefoil	X		7	5	Caledon Lake Wetland
Rhamnus alnifolia	Alder-leaved Buckthorn	X		7	5	Credit River Wetland Acton Wetland Erin Pine Estates Wetland Terra Cotta Wetland Ken Whillans Wetland Caledon Lake Wetland Melville Wetland
Rosa palustris	Swamp Rose	X	X	7	5	Creditview Wetland Warwick Wetland
Rumex orbiculatus	Water Dock	X		6	5	Warwick Wetland Erin Pine Estates Wetland Grange Orpen Wetland Starr Wetland
Salix amygdaloides	Peach-leaved Willow	X			2	Warwick Wetland
Salix candida	Hoary Willow	X	X	10	5	Caledon Lake Wetland
Salix exigua	Sandbar Willow	X		3	5	Credit River Wetland
Salix lucida	Shining Willow	X		5	5	Caledon Lake Wetland
Salix serissima	Autumn Willow	X	X	6	2	Caledon Lake Wetland

APPENDIX C: RARE AND HIGHLY CONSERVATIVE SPECIES OBSERVED AT WETLAND MONITORING SITES (Cont'd)

Latin Name	Common Name	Locally Rare	Regionally Rare	CC Value	Number of Years Detected	Wetland Site
Sarracenia purpurea	Northern Pitcher-plant	X	X	10	5	Caledon Lake Wetland
Sparganium eurycarpum	Large Bur-reed	X		3	5	Creditview Wetland Warwick Wetland Melville Wetland
Stellaria longifolia	Longleaf Starwort	X	X	2	2	Warwick Wetland Starr Wetland Grange Orpen Wetland
Symphyotrichum pilosum var. pilosum	White Heath Aster variety	X	X	4	4	Grange Orpen Wetland Hungry Hollow Wetland Starr Wetland
Utricularia vulgaris	Greater Bladderwort	X		4	4	Speersville Wetland
Vaccinium angustifolium	Late Lowbush Cranberry		X	6	5	Caledon Lake Wetland
Vaccinium macrocarpon	Large Cranberry	X	X	10	2	Caledon Lake Wetland
Vaccinium oxycoccos	Small Cranberry	X	X	10	5	Caledon Lake Wetland
Viola renifolia	Kidney-leaf White Violet	X		7	2	Speersville Wetland Caledon Lake Wetland

APPENDIX D: YEAR OF FIRST DETECTION OF NON-NATIVE WETLAND SPECIES BY THE TERRESTRIAL MONITORING PROGRAM

Table 1. Year of first detection of non-native wetland species in the Credit River Watershed by the Terrestrial Monitoring Program

Latin Name	Common Name	Year of First Detection by Monitoring Program [a]				
		2005	2006	2007	2008	2009
Acer negundo	Manitoba Maple	X				
Acer platanoides	Norway Maple		X			
Achillea millefolium ssp. millefolium	Common Yarrow		X			
Alliaria petiolata	Garlic Mustard	X				
Arctium minus ssp. minus	Common Burdock	X				
Artemisia vulgaris	Common Wormwood			X		
Barbarea vulgaris	Yellow Rocket				X	
Capsella bursa-pastoris	Common Shepherd's Purse			X		
Cerastium fontanum	Common Mouse-ear Chickweed					X
Chelidonium majus	Greater Celadine	X				
Chenopodium album var. album	Lambsquarters			X		
Cirsium arvense	Creeping Thistle	X				
Cirsium vulgare	Bull Thistle		X			
Cynoglossum officinale	Common Hound's-tongue				X	
Dactylis glomerata	Orchard Grass	X				
Daucus carota	Queen Anne's Lace	X				
Elymus repens	Quackgrass			X		
Epilobium hirsutum	Great-hairy Willow-herb				X	
Epilobium parviflorum	Small-flower Willow-herb				X	
Epipactis helleborine	Eastern Helleborine	X				
Geranium robertianum	Herb-robert	X				
Glechoma hederacea	Ground Ivy				X	
Glyceria maxima	Reed Manna-grass		X			
Hesperis matronalis	Dame's Rocket	X				
Hieracium caespitosum	Yellow Hawkweed	X				
Hypericum perforatum	Common St. John's-wort	X				
Impatiens glandulifera	Ornamental Jewelweed	X				
Inula helenium	Elecampane Flower	X				
Leonurus cardiaca ssp. cardiaca	Common Motherwort				X	
Lithospermum officinale	European Gromwell	X				
Lonicera tatarica	Tartarian Honeysuckle	X				
Lotus corniculatus	Birds-foot Trefoil	X				
Lycopus europaeus	European Bugleweed	X				
Lysimachia nummularia	Creeping Jennie		X			
Lythrum salicaria	Purple Loosestrife	X				
Medicago lupulina	Black Medic	X				
Melilotus alba	White Sweet Clover		X			
Melitotus officinalis	Yellow Sweet Clover			X		
Mentha x piperita	Peppermint		X			
Myosotis scorpioides	True Forget-me-not	X				
Nasturtium officinale	True Watercress	X				
Nepeta cataria	Catnip		X			

APPENDIX D: YEAR OF FIRST DETECTION OF NON-NATIVE WETLAND SPECIES BY THE TERRESTRIAL MONITORING PROGRAM (Cont'd)

Common Name	Latin Name	Year of First Detection by Monitoring Program [a]				
		2005	2006	2007	2008	2009
Phleum pratense	Meadow Timothy			X		
Plantago major	Common Plantain			X		
Poa compressa	Canada Bluegrass				X	
Poa trivialis	Rough Bluegrass	X				
Polygonum hydropiper	Marshpepper Smartweed				X	
Potamogeton crispus	Curly Pondweed	X				
Ranunculus acris	Tall Buttercup	X				
Rhamnus cathartica	Common Buckthorn	X				
Ribes rubrum	Garden Red Currant				X	
Rumex crispus	Curly Dock	X				
Salix purpurea	Purpleosier Willow					
Silene vulgaris	Bladder Campion	X				
Solanum dulcamara	Climbing Nightshade	X				
Sonchus arvensis ssp. arvensis	Perennial Sowthistle	X				
Sonchus oleraceus	Common Sowthistle				X	
Sorbus aucuparia	European Mountain-ash	X				
Stellaria graminea	Little Starwort				X	
Taraxacum officinale	Brown-seed Dandelion	X				
Trifolium repens	White Clover	X				
Tussilago farfara	Colt's Foot	X				
Typha angustifolia	Narrow-leaved Cattail	X				
Typha x glauca	White Cattail	X				
Urtica dioica ssp. dioica	Stinging Nettle	X				
Veronica anagallis-aquatica	Water Speedwell			X		
Veronica officinalis	Gypsy-weed				X	
Viburnum opulus	Guelder-rose Viburnum	X				
Vicia cracca	Tufted Vetch	X				

[a] Indicates the year that non-native species were first observed in monitoring plots, not the year that non-natives were first detected within the watershed. 2005 was the year of first detection for many species as it was the first year of the monitoring program.