Credit Valley Conservation

Terrestrial Monitoring Program Report

2002 - 2008

Monitoring Forest Integrity within the Credit River Watershed
Chapter 2: Forest Birds

CVC
CREDIT VALLEY CONSERVATION

Monitoring Forest Integrity within the Credit River Watershed

Chapter 2: Forest Birds 2002-2008

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ABSTRACT

Forest Birds of the Credit River Watershed: Summary of Monitoring Results 2002-2008
Temporal Trends: Species Richness and Relative Abundance increased between 2002 and 2008. Species Diversity and Community Similarity remained stable. Seven guilds, Residents, Short-Distance Migrants, Long-Distance Migrants, Habitat Generalists and Canopy/Sub-Canopy Nesting Species showed increasing population trends between 2002 and 2008. Shrub Nesting and Cavity Nesting Species also showed trends towards significant over the same period. Populations of eight species (American Robin, Black-capped Chickadee, Brown-headed Cowbird, Black-throated Green Warbler, Cedar Waxwing, House Wren, Eastern Wood-Pewee and Red-eyed Vireo) increased. Two species, Northern Flicker and Ovenbird, decreased Watershed-wide.
Spatial Trends: Species Richness was significantly higher in the Middle than Lower Watershed. Relative abundance of birds in eight guilds showed spatial differences among the three Physiographic Zones. Nine species exhibited spatial differences in relative abundance among the three Physiographic Zones
Relationship with Landscape Metrics: Twenty-eight of the forest bird parameters were correlated with at least one of the five following landscape metrics: habitat patch size, percent agricultural cover, percent natural cover, percent urban cover and matrix quality. Observed correlations were consistent with those reported in literature and were related to land-use characterization in the three Physiographic Zones. Forest bird species assemblages could be used to distinguish forests among the three Physiographic Zones. Lower Watershed forests were characterized by urban associates, Middle Watershed forests were characterized by forest specialists and Upper Watershed forests were characterized by Edge/Early Successional Species.
Recommendations: Trends of changing parameters must be watched closely to determine whether intervention will be needed to maintain stable forest bird populations. Although beyond the scope of this report, research should attempt to determine to what scale are species composition and abundance responding (i.e. 100m -5km radius surrounding forest plots).

Forest breeding bird surveys are conducted annually in 25 forest plots in the Credit River Watershed according to Environment Canada's 'Ontario Forest Bird Monitoring Program' (Konze and McLaren 1997). This report summarizes the 7-year review and statistical analysis of forest bird monitoring data collected between 2002 and 2008 in forest plots Watershed-wide.

A total of 114 bird species were detected across the Watershed between 2002 and 2008, four of which were species at risk in Ontario, and five of which were migratory, non-breeding species. Eighty-six of the detected bird species breed in forest habitats. Of the top 10 most abundant species in the Watershed, four are considered to be habitat generalists. Red-eyed Vireo was the most abundant forest bird species detected Watershed-wide.

Species richness and relative abundance were the only community metrics that showed changing trends between 2002 and 2008. Species turnover was less than 30% from year to year. The observed increase in relative abundance was likely a result of increasing population trends of seven guilds and a number of individual species. All three migratory guilds (*i.e.* Resident, Short-Distance and Long-Distance Species), Habitat Generalists, and three nesting guilds (*i.e*. Shrub Nesting, Canopy/Sub-canopy and Cavity-Nesting Species) exhibited significantly or near significant increasing population trends, over the monitoring period. Populations of eight forest bird species significantly increased from 2002 to 2008. An additional two species showed significant declining trends over the monitoring period. Most of the observed population trends were consistent with the National Breeding Bird Survey.

The three Physiographic Zones of the Credit Watershed did exhibit many significant differences in community composition and species abundance. Of the community metrics, spatial trends were only observed for species richness, which was significantly higher in the Middle than the Lower Watershed. Short-Distance Migrants, Habitat Generalists, Edge/Early Successional Species and Shrub Nesting Species were more abundant in the Lower than the Middle and Upper Watersheds. Long-Distance Migrants, Forest Associates, Canopy/Sub-canopy Nesting and Ground Nesting Species were all more abundant in the Middle and Upper Watersheds than the Lower Watershed. Nine species (American Crow, American Robin, Blue Jay, Common Grackle, Downy Woodpecker, Northern Cardinal, Northern Flicker, Ovenbird and Scarlet Tanager) exhibited spatial differences in relative abundance among the three Physiographic Zones, most of which could be explained by land-use differences among the three zones.

Twenty-eight of the thirty-two forest bird parameters were correlated with at least one of the five landscape metrics. Guilds and individual species that were associated with forest habitats and specialized forest features were positively correlated with habitat patch size, percent natural cover and matrix quality. Guilds and individual species that were considered habitat generalists or associated with early successional and shrub habitats were positively correlated with percent urban cover, and negatively correlated with habitat patch size and matrix quality. Guilds and species that were positively correlated with habitat patch size, percent natural cover and matrix quality were also generally more abundant in the Middle and Upper Watershed zones than the Lower Physiographic Zone. Species composition and relative abundance were significantly different among forests in the three Physiographic Zones, so they could be used to distinguish Lower Watershed forests from Upper and Middle Watershed Forests. However, community composition in the Upper and Middle Watersheds were similar. The presence and relative abundance of 25 forest bird species could be used to distinguish among forests in the three Physiographic Zones of the Credit River Watershed. Indicator species for Lower Watershed forests were generally urban associates, indicators of Middle Watershed forests were forest specialists and Upper Watershed forest indicators were Shrub Nesting, Edge/Early Successional habitat associates.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

1.1 BACKGROUND

Ontario has undergone dramatic change since the arrival of European settlers. A landscape that was historically dominated by forest cover has experienced rapid removal of wildlife habitat and fragmentation of remaining natural areas by agriculture, residential development and roads (Larson et al. 1999).

The amount of natural forest cover in a landscape often dictates what forest dependent wildlife species can be supported. Although this is especially evident with the disappearance of large mammals such as the gray wolf (*Canis lupus*) and black bear (*Ursus americanus*) from the highly developed landscapes of southern Ontario, this is also true for smaller organisms such as birds and plants. Forest habitat loss, and therefore reductions in overall natural cover, can negatively affect a species in many ways; some species disappear from the landscape, some species decline in abundance, while others fail to reproduce (Noss and Cooperrider 1994). Forest-dwelling species requiring large habitat patches or specialized habitat conditions are most sensitive to reduced forest cover. While other species, such as urban associates or generalist species may benefit and flourish in disturbed landscapes. Recent studies have revealed that total forest cover may be a better predictor of species richness, diversity and occupancy than forest size, shape and spatial configuration alone, especially once regional cover exceeds 30% (Andren and Nurnburger 1994; McGarigal and McComb 1995; Fahrig 1997; Trzinski et al. 1999; Villard et al. 1999; Fahrig 2002). Research therefore emphasizes the importance of retaining and enhancing existing forest cover within the landscape.

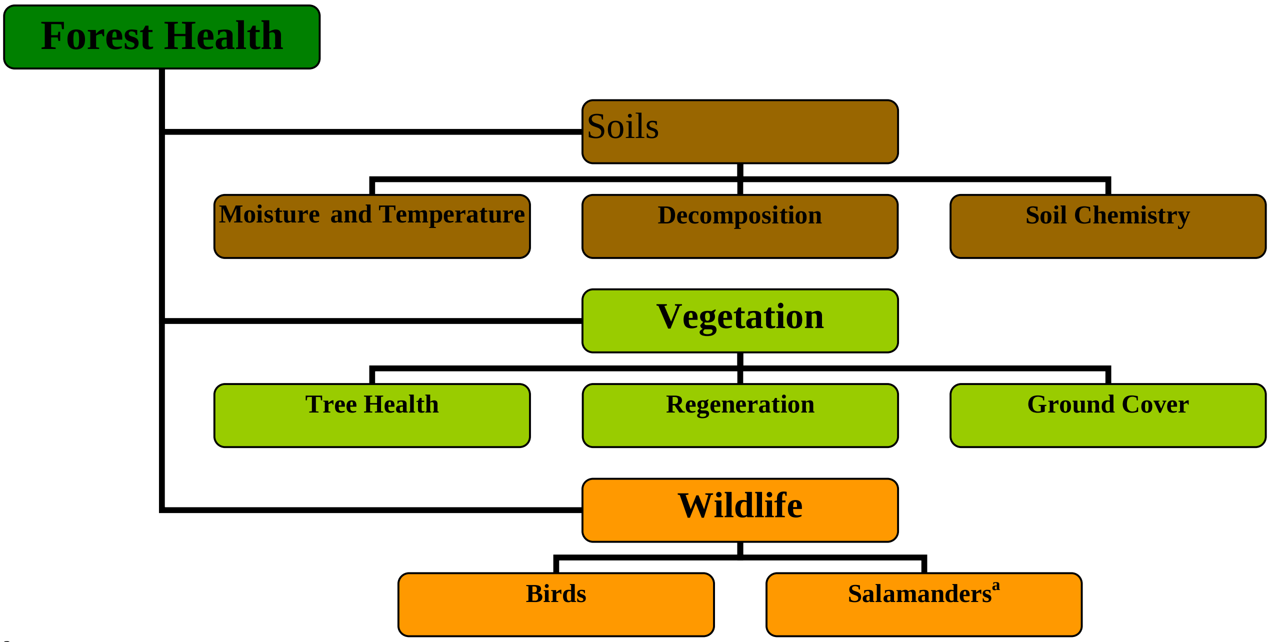
Fragmentation generally results in the reduction of total habitat available, the isolation of remaining patches, decreases in patch size and often an increase in total patch number (Noss and Cooperrider 1994; Fahrig 2002). Plant and wildlife species that are adapted to living in well-connected landscapes now face the challenge of acquiring all resources crucial to survival and reproduction from isolated habitat patches (Beier and Noss 1998). This is especially difficult for species that are poor dispersers or require large home ranges to fulfill their foraging and breeding needs (Andren and Nurnburger 1994). Isolation from other patches can result in reduced ability to secure required resources, reduced gene flow and ultimately extirpation of a species (Fleury and Brown 1997). Habitat loss and fragmentation can therefore have serious implications for populations, biodiversity and ecosystem functioning (Hess and Fischer 2001; Noss and Cooperrider 1994).

Forest cover levels are lower in southern Ontario than anywhere else in the province. The Carolinian zone has dropped from an estimated pre-settlement value of 80% forest cover to 11% (Larson et al. 1999). In 2002, the dominant land use in the Credit Watershed was agricultural at 37%, followed by urban development at 29%, natural cover at 23% and successional community cover at eleven percent. Remaining forest cover in the Credit River Watershed is at 12%, much below Environment Canada's recommended minimum value of 30% forest cover in a watershed to sustain stable and 'healthy' populations of wildlife species (Environment Canada 2004).

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 link 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 (Credit Valley Conservation 2010). Within the watershed several forest monitoring stations have been established in which soil, vegetation and wildlife parameters are measured to describe forest conditions in the watershed and to monitor trends over a 25 year period (Fig. 1&2).



[a]monitoring to begin in 2011

Figure 1. Forest health parameters in the Credit River Watershed

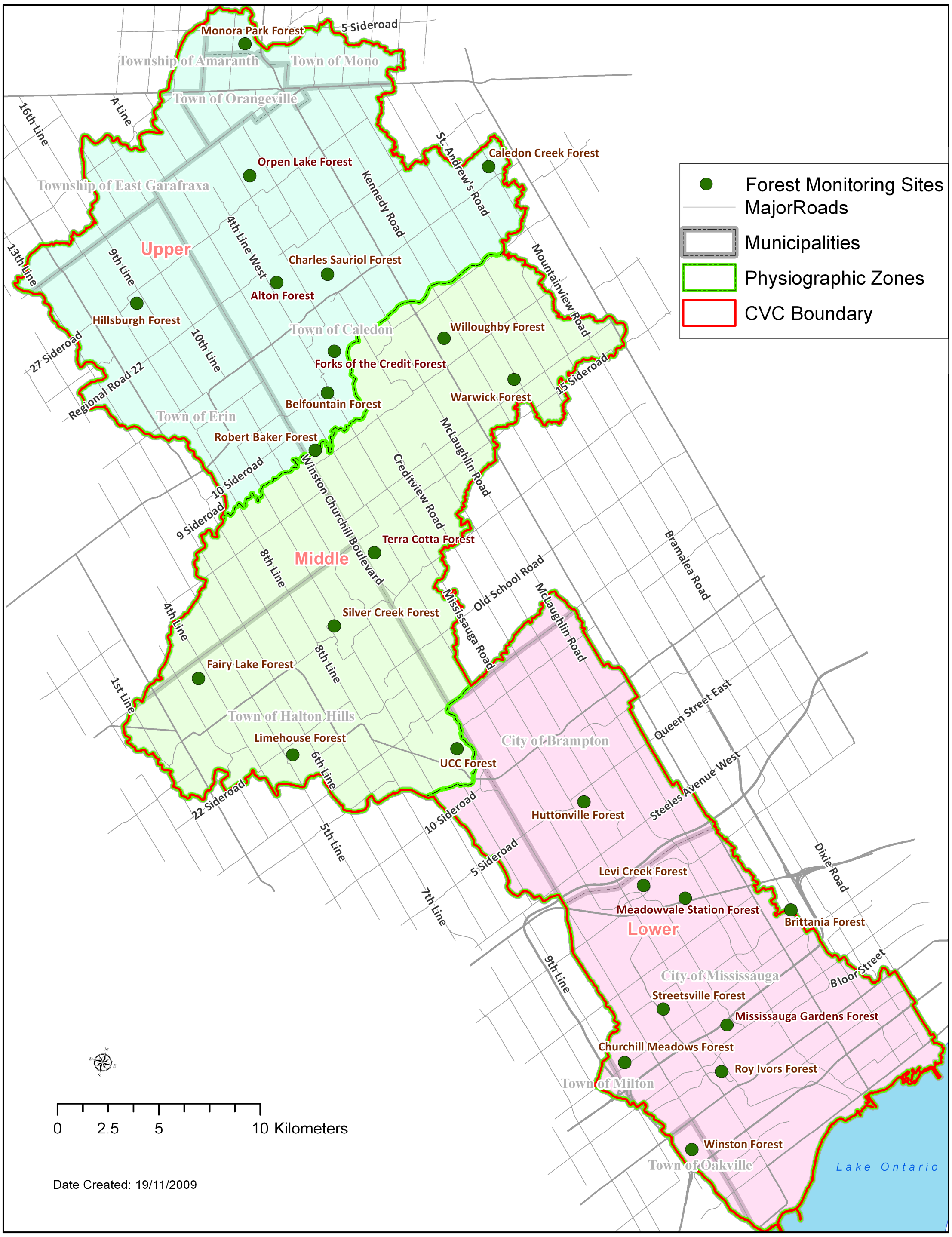


Figure 2. Forest Monitoring sites in the Credit River Watershed

1.3 WHY MONITOR FOREST BIRDS?

Forest birds, with a special emphasis on songbirds, have often been used as surrogates for the health and status of wildlife species and natural communities. This is because individual bird species, populations and communities are sensitive to habitat changes that have been shaped by reduced forest cover, habitat fragmentation and land-use practices. Relative to other taxons, forest birds are easily surveyed and the habitat requirements and sensitivities are well known for many of the species, making them ideal indicators of ecosystem health.

It is well established that long-distance migratory songbirds have been undergoing significant population declines since 1966 (Rappole and McDonalds 1994), with approximately 71% of eastern migrants displaying negative population trends between 1978 and 1987 (Roberts and Norman 1999). Some of the most significant population declines continent-wide have been observed in forest breeding migratory bird species (Roberts and Norman 1999). Declines have been attributed to a combination of the following three processes: 1) increased mortality as they migrate; 2) increased mortality on wintering grounds due to changes in habitat (i.e. deforestation); and 3) reduced fecundity and fitness on breeding grounds due to habitat loss and/or fragmentation (Martin and Li 1992; Sherry and Holmes 1993; Burke and Nol 1998; Holmes and Sherry 2001). Declining forest bird populations continent-wide, combined with an increasing loss of forest specialist bird species within urbanizing areas such as the GTA (Environment Canada 2004) have therefore promoted population monitoring of Forest Birds within the Credit River Watershed.

1.4 FOREST BIRD RESPONSES TO A CHANGING LANDSCAPE

Landscape effects on breeding songbird richness, abundance and reproductive success are well studied in North America. Although some of the responses are species or regional specific, generalizations can be made about the overall effects of habitat loss, fragmentation and land-use change on bird communities.

Percent forest cover has a positive effect on forest bird species richness, diversity and abundance (Andren and Nurnburger 1994; McGraigal and McComb 1995; Fahrig 1997; Fahrig 1998; Trzinski et al. 1999). In fact, the persistence of many forest bird species is expected once regional forest cover exceeds 30% (Fahrig 1997). Although Burke and Nol (2000) found that there was no significant effect of local forest cover on the productivity of five migratory songbirds, the study was conducted in a region of the province where local forest cover exceeded fifty percent.

Forest bird species richness, abundance and reproductive success are more heavily influenced by habitat fragmentation and spatial configuration once regional forest cover values dip below 30% (Andren and Nurnburger 1994; Villard et al. 1995; Fahrig 1997). Negative effects of fragmentation on forest bird population dynamics include increased mortality of individuals moving between forest patches, lower re-colonization rates of empty patches and reduced local population sizes resulting in increased susceptibility to extinction (Fahrig and Merriam 1994). Many forest bird species also experience higher nest failure rates in fragmented versus contiguous landscapes (Donovan et al. 1995; Burke and Nol 2000) due to higher frequencies of brood parasitism (Brittingham and Temple 1983) and nest predations (Robinson 1992; Wilcove 1985). Fragmentation not only results in the loss of total habitat, but generally increases the availability of edge habitat and decreases habitat diversity (Mayer and Cameron 2003). Both nest predation and brood parasite (Brown-headed Cowbird) densities are higher in edge habitats than in forest interiors (Donovan et al. 1995; Burke and Nol 2000). Villard et al. (1995) also found that forest specialist bird species such as the Ovenbird and Scarlet Tanager were positively correlated with proximity to nearest forest fragment. The influence of forest patch size on forest bird communities has been well studied in North America. Species richness, abundance and reproductive success increase with increasing woodlot size (Blake and Karr 1987; Donovan et al. 1995; Villard et al. 1995; Burke and Nol 2000). Larger forest patches generally have higher habitat heterogeneity and diversity, which results in higher forest bird species richness (Freemark and Merriam 1986; Blake and Karr 1987). The diversity of habitats in larger patches is believed to increase bird species richness by allowing the co-occurrence of a greater number of species as species-specific habitat requirements are met (Karr 1971; Blake and Karr 1987), and by reducing the potential for competition between species by allowing for spatial segregation within a patch (Martin 1987; Blake and Karr 1987). Overall, bird communities in small forest patches are dominated by habitat generalists, with forest specialists increasing in abundance and importance as patch size increases (Blake and Karr 1987). Burke and Nol (2000) also found that reproductive success was influenced by forest patch size for a community of migratory songbirds. More specifically, forest predation and nest abandonment rates were significantly lower in larger forest patches with core area than small forest patches. Impacts of fragmentation on forest demography are capable of creating population sinks in forest fragments, in which case long-term sustainability of certain populations are dependent on immigration to small patches from larger source populations (Donovan et al. 1995).

It is important to note that the effects of fragmentation on bird communities are heavily influenced by the landscape matrix within which the remaining forest patches are embedded (Askins et al. 1987; Andren 1992; Friesen et al. 1995; Donovan et al. 1995). Different land-uses influence the taxonomic diversity and structural complexity of vegetation, which affect the availability of nest sites and foraging microhabitats (James and Warner 1982; Martin 1987; Martin 1988; Haskell 1995). Communities of nest predators also change in composition and abundance in response to land-use (Angelstam 1986; Andren 1992; Hannon and Coterill 1998; Saab 1999). Forest patches in agricultural landscapes have higher levels of nest predation and brood parasitism rates, lower species richness and lower abundances of forest specialist bird species than forest patches in forested landscapes (Burke and Nol 2000; Thompson 2000; Rodewald and Yahner 2001). Relative to forested landscapes, forest patches in an urban matrix generally have higher bird abundance, lower species richness and diversity, and altered species composition in which a few species become dominant (Friesen et al. 1995; Blair 1996). Species that are able to exploit urban environments are able to develop dense and stable populations because of ameliorated climate, increased food and water availability and decreased abundances of forest associated predators, which ultimately result in lengthened breeding seasons, decreased annual mortality rates and increased productivity (Marzluff 2001).

However, urban matrices are not as favourable to forest associates, for who nest predation and parasitism rates increase, which result in reduced abundances of ground nesting and interior bird species (Marzluff 2001). Declines in bird species richness, abundance and reproductive success in urban landscapes are linked to decreased habitat availability, decreased patch size, increased edge habitat, increases in non-native vegetation, degreased vegetation complexity, increases in predators, parasites and competitors, and intolerance to human activities (Marzluff 2001).

Overall, landscape metrics have the capability to change ecosystem processes, habitat availability, food availability, predator abundance, predator composition and competitor densities. All of these changes can influence populations of forest bird species, resulting in effects on overall structure and composition of bird communities in the Credit River Watershed. Therefore, observed population trends and bird community composition will be considered within the context of the changing landscape of the Credit River Watershed.

1.5 OBJECTIVE: MONITORING QUESTION

Concerns about the local population stability of forest birds and how it relates to watershed health prompted forest bird monitoring in the Credit River Watershed in 2002 to answer the question:

ARE POPULATION TRENDS OF FOREST BIRDS IN THE CREDIT WATERSHED STABLE?

More specifically, 1) are species richness, species diversity and forest bird abundance changing through time (2002-2008); 2) has forest bird community composition changed in the watershed from year to year; 3) are any guilds or individual species experiencing population changes over the 7 year monitoring period; and 4) do community parameters, and relative abundance of guilds and individual species differ spatially throughout the Credit Watershed (Table 1).

Trend analyses were used to examine parameters of interest for increasing or decreasing trends over time, and temporal analyses were used to examine whether or not differences occurred between years. Spatial analyses were used to examine whether there was a difference among the three Physiographic Zones in the Credit River Watershed. Bird guilds examined include the abundance of individuals with a low tolerance for disturbance to forest habitats such as Forest Associates and Ground Nesting Species, the abundance of species that have exhibited population declines continent-wide such as Aerial Foragers and Long-Distance Migrants, as well as densities of species that often flourish in urbanizing landscapes such as Generalist, Edge/Early Successional and Shrub Nesting Species (see Methods section for details).

Table 1. Forest bird monitoring framework for the Credit River Watershed

Monitoring Question	Monitoring Variable [a]	Unit of Measurement	Analysis Method
Trend Analyses			
Is forest bird species richness changing over time in the Credit Watershed?	Number of Species	Count	-Trend Analysis: Linear Regression - Power Analysis - Statistical Process Control
Is forest bird species diversity changing over time in the Credit Watershed?	Shannon-Weiner Function	Index	-Trend Analysis: Linear Regression - Power Analysis - Statistical Process Control
Is forest bird community composition changing from year to year in the Credit Watershed?	Jaccard's Index	Index	-Trend Analysis: Linear Regression - Power Analysis - Statistical Process Control
Is forest bird abundance changing over time in the Credit Watershed?	Relative abundance (# birds detected watershed- wide /year)	Count	-Trend Analysis: Poisson Regression - Power Analysis - Statistical Process Control
Are any guilds experiencing population increases or declines in the Credit River Watershed?	Relative abundance (total # birds belonging to a guild detected watershed- wide / year)	Count	-Trend Analysis: Poisson Regression - Power Analysis - Statistical Process Control
Are any individual species experiencing population increases or declines in the Credit River Watershed?	Relative abundance (#birds detected watershed-wide/year)	Count	-Trend Analysis: Poisson Regression - Power Analysis - Statistical Process Control
Spatial Analyses			
Are there spatial differences in species richness in the Credit River Watershed?	Number of species detected per site	Count	-Repeated Measures ANCOVA - Power Analysis
Are there spatial differences in species diversity in the Credit River Watershed?	Shannon-Weiner Function per site	Index	-Repeated Measures ANOVA - Power Analysis
Are there spatial differences in bird abundance in the Credit River Watershed?	Relative Abundance (# birds/point/site/year)	Count	-Repeated Measures ANOVA - Power Analysis
Are there spatial differences in guild abundance in the Credit River Watershed?	Relative Abundance (#birds in guild/point/site/year)	Count	-Repeated Measures AN(C)OVA parametric parameters - Friendman Test and Kruskal Wallis Test for non-parametric parameters - Power Analysis

Monitoring Question	Monitoring Variable [a]	Unit of Measurement	Analysis Method
Spatial Analyses (Continued)			
Are there spatial differences in the relative abundance of individual species in the Credit River Watershed?	Relative Abundance (total number of individual species/point/site/year)	Count	-Repeated Measures AN(C)OVA for parametric parameters - Friendman Test and Kruskal Wallis Test for non-parametric parameters - Power Analysis
Landscape Analysis			
Were forest bird parameters correlated with landscape metrics in the Credit River Watershed?	Bird guilds. Total species abundance, species richness and species diversity were compared to habitat patch size, % urban, natural and agricultural cover, and matrix quality	Variable	-Spearman Rank Correlation
Community Analyses			
Do forests in the three Physiographic Zones have unique species assemblages?	Relative Abundance of each species (#species/point/site/year)	Count	- Multi-response Permutation Procedure (MRPP) - Indicator Species Analysis

[a]All monitoring variables were summarized for each individual site in each year across the monitoring period.

2.0 METHODS

2.1 BIRD SURVEYS

The relative abundance of forest breeding bird species in the Credit Watershed between 2002 and 2008 were estimated by following Environment Canada's 'Ontario Forest Bird Monitoring Program' (Konze and McLaren 1997). Every year, unlimited distance point-count surveys were conducted at one to five permanent point-count stations at each of the 25 forest plots (Appendix A). One station was located in the centre of the Terrestrial Monitoring Forest Plot, with all other points separated by at least 250 m to avoid double-counting the same individuals. Each station was visited twice between May 24 and July 5, between 5:30 am and 10:30 am. Surveys were not conducted during rain or when winds exceeded 15 km hr^{-1}. All birds heard or seen during the 10 minute point count surveys were counted, identified to species, and where possible, notes on breeding status and/or bird behaviour were recorded. Although birds flying over ('flyovers) the site were noted, they were not included in analyses.

2.2 DATA PREPARATION

Prior to analyses, all observations of birds not associated with forest habitats were removed from the data set. This included species associated with open fields or agricultural areas such as Bobolink *(Dolichonyx oryzivorus)* or Savannah Sparrow *(Passerculus sandwichensis)*, marsh species such as the American Coot *(Fulica americana)* and urban associates such as the Rock Pigeon *(Columba livia)* and House Sparrow *(Passer domesticus)*. Species associated with forests, but not considered to be breeders within Credit River Watershed were included in richness estimates, only if detected after June 7. Flyover observations were also excluded from analyses.

For each species, relative abundance per point per year was calculated by taking the maximum count recorded across the two visits. For forest stands with more than one point count station, these values were summed to provide a stand total, per species, per year. Relative abundance of each species was then calculated per point per site per year, by taking the max abundance per point per site per year, so all sites could be compared regardless of variable station numbers among sites. Species richness per site was calculated by counting all species detected at all point count stations. For comparisons among sites, this value was divided by the number of point count stations in each site respectively. Watershed-wide species abundance and richness was a sum of all stand totals (using the maximum count as mentioned above).

2.2.1 Bird Guilds

Birds detected by the monitoring program were also grouped into eleven guilds based on migratory behaviour, general habitat associations, nesting preferences and foraging niches (Appendices C-E). Root (1967) defined guilds as "*a group of species that exploit the same class of environmental resources in a similar way*". If selected carefully, guilds can represent the "basic building blocks" of communities (Hawkins and MacMahon 1989; Simberloff and Dayan 1991). Root (1967) listed three main advantages to using guilds in community studies: 1) guilds are composed of all competing species regardless of taxonomy, 2) guild reduces the dual usage of the term niche, and 3) guilds enable us to study groups of functionally similar species thereby providing a shortcut to studying individual species responses (Root 1967). This is especially important as many individual species were not detected in sufficient numbers to analyze independently. The following guilds were created by referring to peer-reviewed journal articles and books (Ehrlich et al. 1988; Freemark 1989; Lichstein et al. 2002; Denford and Freemark 2004), the Ontario Breeding Bird Atlas (Cadman et al. 2008) and by holding a workshop with a panel of local experts in 2010 to confirm the groupings were appropriate to bird behaviour in the Credit River Watershed.

Migratory Behaviour:

1. Resident Bird Species- forest bird species that reside in the watershed year-round.
2. Short-Distance Migrants- forest bird species that migrate short distances without leaving North America, often in response to seasonal fluctuations in food and weather extremes.
3. Long-Distance Migrants- often referred to as neo-tropical migrants, these species migrate long distances to Central and South America.

General Habitat Associations:

4. Forest Associates- forest bird species that require forest habitats for nesting and often specialized forest habitat features such as mature closed canopy conditions, forest interior, large areas, large diameter trees or downed woody debris.
5. Edge/ Early Successional Species- forest bird species often associated with forest edges, gaps, and early successional patches, many of which nest in shrubs.
6. Habitat Generalists- forest bird species that utilize a variety of habitats including forests, parks and residential areas.

Nest Site Preferences:

7. Ground Nesting Species- forest bird species that build open-cup nests on or close (within 30 cm) to the ground.
8. Shrub/Mid-level Nesting Species- open-cup forest bird species that primarily nest in shrubs and occasionally saplings (30 cm to 3 m above the ground).
9. Canopy/ Sub-canopy Nesting Species- open-cup forest bird species that primarily nest in tree sub-canopies or canopies (>3m above the ground).
10. Cavity Nesting Species- forest bird species that build their nests in tree cavities (natural or excavated).

Foraging Specialization:

11. Aerial Insectivores- bird species that nest and/or forage in forests, that capture insects on the wing as defined by Bird Studies Canada.

2.2.2 Community Metrics

2.2.2.1 Species Richness. Richness (alpha diversity) was calculated by counting the number of unique forest bird species identified Watershed-wide, per year. Richness calculations were also completed for each individual site, per year.

2.2.2.2 Species Diversity. Forest bird species diversity in the Credit River Watershed was calculated using the Shannon-Weiner Function:

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

Where H^1 = Index of species diversity
s = Number of species
p_i = Proportion of total sample belonging to ith species

This was calculated both Watershed-wide per year as well as at the site level for every year. Values above 3.5 are considered to represent communities with high species diversity.

2.2.2.3 Community Similarity. Forest Bird Community change or annual turnover among years was calculated using Jaccard's Similarity Index:

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

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

Community similarity values (beta diversity) were calculated watershed-wide for 2002 vs. 2003, 2003 vs. 2004, 2004 vs. 2005, 2005 vs. 2006, 2006 vs. 2007 and 2007 vs. 2008. Percent community dissimilarity among years was calculated by subtracting Jaccard's similarity coefficient from 1 and multiplying by 100 (Krebs 1999).

2.3 STATISTICAL ANALYSES

2.3.1 Trend and Temporal Analyses

Population trends of forest birds in the Credit River Watershed were analyzed using the general linear model (GLM) Exact Non-parametric Inference Poisson Regression test in R version 2.11.1 (R Foundation for Statistical Computing). Poisson regression was used for population trend analysis because count data often follows a Poisson distribution, where the mean equals the variance (Ter Braak 1994). This methodology is further supported by Ter Braak (1994) who after evaluating five commonly used methods to analyse bird population data, concluded that Poisson Regression was the most accurate and promising approach to assess population trends, annual indices and effects of covariates. Exact tests were used rather than asymptotic models because they do not assume that data are normally distributed. Results were considered significant when $P<0.05$ (Zar 1999) but discussed when $P<0.10$ to stay consistent with the Canadian Breeding Bird Survey (Downes and Collins 1996) and to avoid committing a Type II Error which can have serious implications in conservation biology (Moran 2003, Nakagawa 2004). The slope of each regression equation represents percent annual population change.

Watershed-wide population trends were analyzed for all species combined. Species-level population trends were also analyzed Watershed-wide, for bird species that were detected across all monitoring years and whose mean abundance was greater than or equal to 10 individuals over the sampling period (2002-2008). Twenty-seven of the 86 forest bird species detected in the watershed were abundant enough to be analyzed independently according to the above mentioned criteria. Bird species that were detected in sufficient numbers in the different Physiographic Zones were also analyzed to determine whether trends in the three Physiographic Zones were consistent with those observed watershed-wide.

Population trends of the eleven bird guilds were also analyzed Watershed-wide and by Physiographic Zone, using the general linear model (GLM) Exact Nonparametric Inference Poisson Regression test R version 2.11.1 (R Foundation for Statistical Computing). Relative abundance values input into the analyses were the sum maximum abundance of all species belonging to a particular guild (Appendices C & D).

Trends of community metrics between 2002 and 2008 were analyzed using linear regression in STATISTICA 7.0 (Statsoft Inc.), with results considered significant when $P<0.05$. The slope of each regression equation represents percent annual change in a community metric.

2.3.2 Spatial Patterns of Bird Communities in the Credit River Watershed

To examine spatial patterns of forest bird communities in the Credit Watershed, monitoring sites were grouped into three Physiographic Zones; Upper, Middle and Lower Watershed. It is hypothesized that differences in land-use cover and landscape configuration among the three zones are likely to influence forest health parameters, including species richness, diversity and relative abundance. The Lower Watershed is dominated by urban cover at 57%, compared to 15% in the Upper and Middle Watershed zones. The Upper Watershed contains the greatest proportion of agricultural and semi-natural (successional) communities (56% combined) relative to the Middle (51%) and Lower Watersheds (34%). The Middle Watershed has the greatest proportion of natural cover at 33%, with the Upper Watershed containing 27% and Lower zone containing 7%

natural cover. In addition to land-use, the configuration and overall character of existing natural cover also differs among the three Physiographic Zones. The dominant forest types in the Middle and Lower zones are deciduous and mixed-deciduous, compared to the Upper Watershed where forests are represented equally by coniferous and deciduous habitat types. On average, woodland units, composed of forest, plantation, cultural woodland and treed swamp communities (Lee et al. 1998), are larger in the Middle than the Lower and Upper Physiographic Zones. Forty-six percent of all patches greater than 20 ha in size are found in the Middle Physiographic Zone, including the only seven patches within Credit River Watershed boundaries that are greater than 200 ha in size (Credit Valley Conservation 2007). Larger habitat patches are of particular importance to breeding bird diversity as they are able to sustain communities of forest specialists such as area sensitive or edge intolerant bird species. Landscapes dominated by small habitat patches are usually characterized by a high abundance of only a few generalist bird species that are tolerant of edge habitats and disturbances associated with non-forested communities. Overall, forests in the Lower Watershed are smaller, more highly fragmented and embedded in a less hospitable matrix than forests in the Upper and Middle Watersheds. The Middle Watershed is part of the protected Niagara Escarpment and Oak Ridges Moraine, which is characterized by larger, more connected forest patches surrounded by a diversity of habitat types. The Upper Watershed is similar to the Middle Physiographic Zone, except for its higher proportion of agricultural land and successional communities. Although birds are highly mobile relative to many other wildlife species, all of the above mentioned landscape parameters are hypothesized to influence bird species composition, abundance and reproductive success to varying degrees. Spatial analyses with consideration to landscape composition and configuration will therefore provide deep insight into potential mechanisms driving observed population trends and patterns.

Data were analyzed with STATISTICA 7.0 (Statsoft Inc.) or SPSS 16.0 (SPSS Inc.), with results considered significant when $P<0.05$ (Zar 1999). Data were tested for normality and homoscedasticity using Shapiro-Wilks and Levene's test for homogeneity of variance, respectively. Non-parametric data were log or square-root transformed to meet the assumptions of normality. Where data could not be normalized, the non-parametric equivalent test was used to complete analyses.

Repeated –measures ANOVA (Analysis of Variance) and Repeated-measures ANCOVA (Analysis of Covariance) were used to compare species richness, species diversity, guild abundance and species relative abundance among the three Physiographic Zones. Forest size was used as a covariate in the Repeated-measures ANCOVA for parameters that were influenced by area. All response variables (species richness, species diversity, guild abundance and species relative abundance) were tested in Statistica 7.0 for a significant relationship with forest size and homogeneity of slopes. Response variables that fulfilled the two criteria were analyzed with Repeated-measures ANCOVA in SPSS 16.0, otherwise Repeated-measures ANOVA was run in STATISTCA 7.0. Tukey's HSD tests for unequal sample sizes were used for post-hoc comparisons. Bonferroni corrections were not used to reduce the likelihood of a Type II Error (Moran 2003, Nakagawa 2004). Friedman Test was used to identify differences among sampling periods (2002-2008) for non-parametric data. Kruskal-Wallis Test was then conducted on annual data sets to identify differences among the three Physiographic Zones for the non-normalized data. Repeated-measures ANOVA or ANCOVA were only run for individual bird species that were detected in at least 5 sites within each of the three Physiographic Zones (i.e. were present in at least 15 sites watershed-wide).

2.3.3 Landscape Analysis

To increase understanding of the relationships between forest bird populations and the landscape which surround them, Spearman Rank correlations were used to determine if monotonic associations exist between bird 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 forest bird parameter across the monitoring period (parameters listed in Table 2), to habitat patch size, matrix quality, and finally percent agriculture, natural and urban area within a 2km 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 2007).

Spearman Rank correlations were completed using STATISTICA 7.0 (Statsoft Inc.), with results considered significant when $P<0.05$. It is well established that habitat patch size has the potential to influence species abundance, richness and reproductive success. A radius of 2km was chosen for the scope of the above landscape composition parameters to be consistent with other research on bird responses to landscape matrix, and to remain consistent with trends described in vegetation parameters. In addition, this distance has been used in other local monitoring studies to examine matrix influence, as it is the distance within which most species dispersal can be expected for most floral and faunal species (Toronto and Region Conservation Authority 2007).

Habitat patch is defined as a continuous patch of natural land cover in a given area, in which the monitored forest area is included, and is comprised of forests, wetlands and successional communities. A 30m buffer was developed around the centre of the monitoring site, and the percentage of natural, urban and agricultural land use was calculated within a 2km radius from the edge of the buffer. 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 (Toronto and Region Conservation Authority 2007).

Table 2. Summary of temporal and spatial analyses used for forest bird parameters within the Credit River Watershed.

Forest Bird Variable	Parametric Trend Analysis	Parametric Temporal and Spatial Analyses	Non-Parametric Temporal and Spatial Analyses	No Temporal and Spatial Analyses
Community Metrics				
Species Richness	X	**X**		
Species Diversity	X	X		
Species Abundance	X	X		
Guilds				
Migratory Guilds				
Resident Species	X	X		
Short-Distance Migrants	X		**X**	
Long-Distance Migrants	X	**X**		
Nesting Guilds				
Forest Associates	X	**X**		
Edge/Early Successional Species	X	**X**		
Habitat Generalists	X	**X**		
Nesting Guilds				
Ground Nesting Species	**X**	**X**		
Shrub Nesting Species	X	**X**		
Canopy/Sub-canopy Nesting Species	X	**X**		
Cavity-nesting Species	X	**X**		
Foraging Guild				
Aerial Foragers	X	X		
Individual Species				
American Crow	**X**	**X**		
American Robin	X	**X**		
Black-capped Chickadee	**X**	X		
Black-throated Green Warbler	X			**X**
Blue Jay	**X**		**X**	
Brown-headed Cowbird	X			**X**
Cedar Waxwing	X			**X**
Chipping Sparrow	X			**X**
Common Grackle	X	**X**		
Downy Woodpecker	X	**X**		
Eastern Wood-pewee	X	**X**		
Great Crested Flycatcher	X	X		
Hairy Woodpecker	X	X		
House Wren	X			**X**
Indigo Bunting	X			**X**
Northern Cardinal	X		**X**	
Northern Flicker	X	X		

Forest Bird Variable	**Parametric Trend Analysis**	**Parametric Temporal and Spatial Analyses**	**Non-Parametric Temporal and Spatial Analyses**	**No Temporal and Spatial Analyses**
Individual Species (Continued)				
Ovenbird	X	**X**		
Pine Warbler	X			**X**
Red-eyed Vireo	X		X	
Rose-breasted Grosbeak	X		**X**	
Scarlet Tanager	X	**X**		
Song Sparrow	X			X
Veery	X			X
White-breasted Nuthatch	X	X		
Wood Thrush	X	X		

2.3.4 Bird Community Composition and Structure

2.3.4.1 Multi-Response Permutation Procedure & Indicator Species Analysis. To test the differences in community composition among the three Physiographic Zones, Multi-Responses Permutation Procedure (MRPP) was computed in PC-ORD 5.0 (McCune and Grace 2002). MRPP is a non-parametric procedure used to test differences between two or more a priori groups (in this case, bird communities in three Physiographic Zones), based on Euclidean distances. The test statistic describes the separation among groups in n-dimensional space. The more negative the test statistic, the stronger the separation among groups. The probability value (p) is the likelihood of finding a difference among groups that is stronger or more extreme than the observed difference among groups. MRPP was run for each year independently (McCune and Grace 2002).

Indicator Species Analysis was conducted in PC-ORD 5.0 following MRPP to describe what forest bird species best discriminate among the three Physiographic Zones. A Blocked Multi-Response Permutation was conducted in PC-ORD 5.0 to test the difference in species composition among years. Because there was no effect of year on community composition, data from all years were lumped together. Indicator Species Analysis uses the relative abundance of a species in each pre-defined group (in this case from each Physiographic Zone) and the faithfulness of its occurrence in the groups (Physiographic Zones) to produce indicator values. Indicator values range from zero to 100, where zero represents no indication and 100 is a perfect indicator, found exclusively in one group. Monte Carlo Test was used to test the ability of each species to statistically differentiate among the bird communities in the three Physiographic Zones at a $P < 0.05$ (McCune and Grace 2002).

2.3.5 Statistical Process Control and Threshold Identification

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.).

Statistical Process 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. 3) (Maurer et al. 1999). 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.

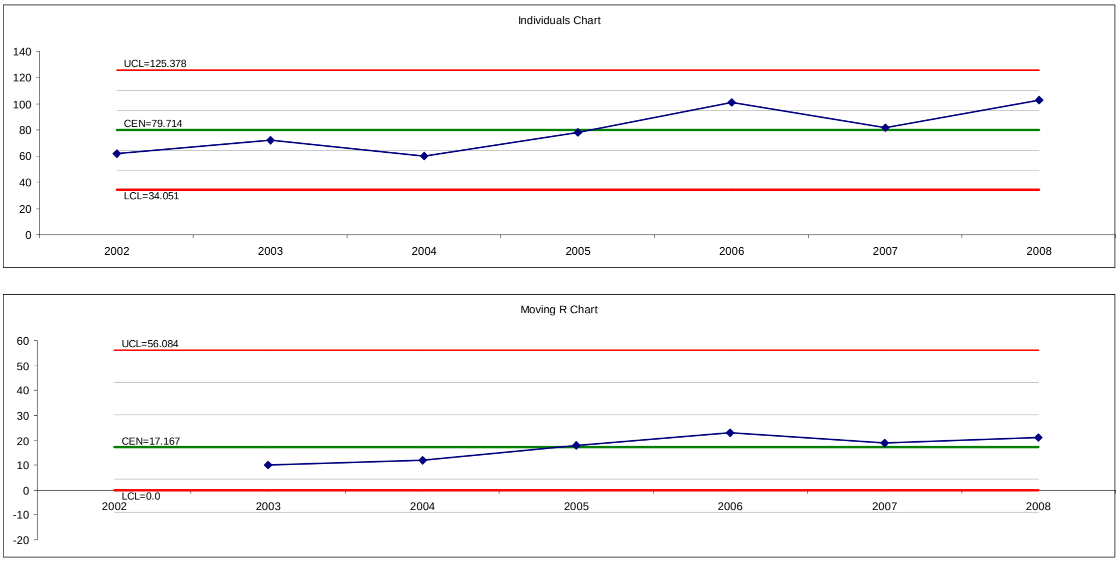


Figure 3. Example of a Statistical Control Chart for the American Robin. Both the Individual Moving Average (top) and Moving Range Charts (bottom) are 'in control' between 2002 and 2008, allowing for monitoring thresholds to be established from these data

For this study Individual Moving Average and Moving Range Charts were examined to determine if each forest bird 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 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.

2.3.6 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 forest bird parameters. Power analysis also assessed the ability of the current monitoring program to detect statistical differences in forest bird 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 statistical process control, 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 forest vegetation communities. Currently, five years of in control data are being 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, except for Repeated Measures ANOVA. These results were used to determine the quality of current monitoring data. Data quality was assessed according to Table 3, 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 (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.

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

Data Quality	Effect size		Confidence	Power
	Linear Regression and Poisson Regression	Repeated Measures ANOVA		
Green	<20% change	Currently have enough sites to detect a significant relationship	80%	90%
Yellow	>20% <40% change	N/A	80%	90%
Red	>40% change	Currently do not have enough sites to detect a significant relationship	80%	90%

3.0 RESULTS AND DISCUSSION

3.1 DESCRIPTIVE RESULTS

3.1.1 General Bird Species Composition

Monitoring Question: How many breeding bird species were detected watershed-wide?

-In total, 108 breeding bird species were detected watershed-wide between 2002 and 2008.

Over the seven year monitoring period, a total of 108 breeding bird species were detected at forest plots, which represents 69% of the 157 bird species that are known to breed in the Credit River Watershed. An additional seven species including five migratory non-breeding species, the Bay-breasted Warbler (*Dendroica castanea*), Blackpoll Warbler (*Dendroica striata*), Swainson's Thrush (*Catharus ustulatus*), Tennessee Warbler (*Vermivora peregrine*) and Wilson's Warbler (*Wilsonia pusilla*), as well as unconfirmed breeders Double-crested Cormorant (*Phalacrocorax autritus*) and Ring-billed Gull (*Larus delawarensis*) were also detected in the watershed. Although not included in the total species count, their presence in the Credit River Watershed emphasizes the importance of these forests as critical stopover habitat.

According to the Ontario Breeding Bird Atlas (Cadman et al. 2008) forty-nine of the observed species were considered forest associates (Fig. 4, Appendix B). The remaining species detected were identified as shrub/early successional, wetland, open habitat or urban associates. Based on a workshop held by CVC in 2010, bird species were reclassified by local experts into general habitat guilds based on their behaviour within the Credit River Watershed. All species considered to nest in habitats encompassed by forest communities (*i.e.* including forest gaps or along edge habitats) were separated from non-forest breeders, for a total of 86 species, or 75% of the birds observed over the seven year period (Appendices C-E). Bird species that do not breed in forest habitats were often detected as distant observations and their relative abundance estimates were therefore not representative of true densities Watershed-wide. Different monitoring protocols are necessary to accurately assess bird communities of non-forest habitats and because these methods have not been conducted as part of the Terrestrial Monitoring Program to date, all non-forest bird species were extracted from further analyses.

Of the 86 forest associate bird species, three non-native species, the European Starling (*Sturnus vulgaris*), House Finch (*Carpadacus mexicanus*) and Ring-necked Pheasant (*Phasianus colchicus*) were detected in forest communities. The two remaining non-native species, House Sparrow *(Passer domesticus)* and Rock Pigeon *(Columba livia)* were detected in open or urban areas adjacent to forest plots, and therefore not included in analyses.

Between 2002 and 2008, four species at risk were detected in the Watershed; the nationally threatened Chimney Swift (*Chaetura palagica*) and Canada Warbler (*Wilsonia canadensis*), the nationally and provincially threatened Hooded Warbler (*Wilsonia citrina*), and the nationally and provincially designated species of concern, Louisiana Waterthrush (*Seirus motacilla*).

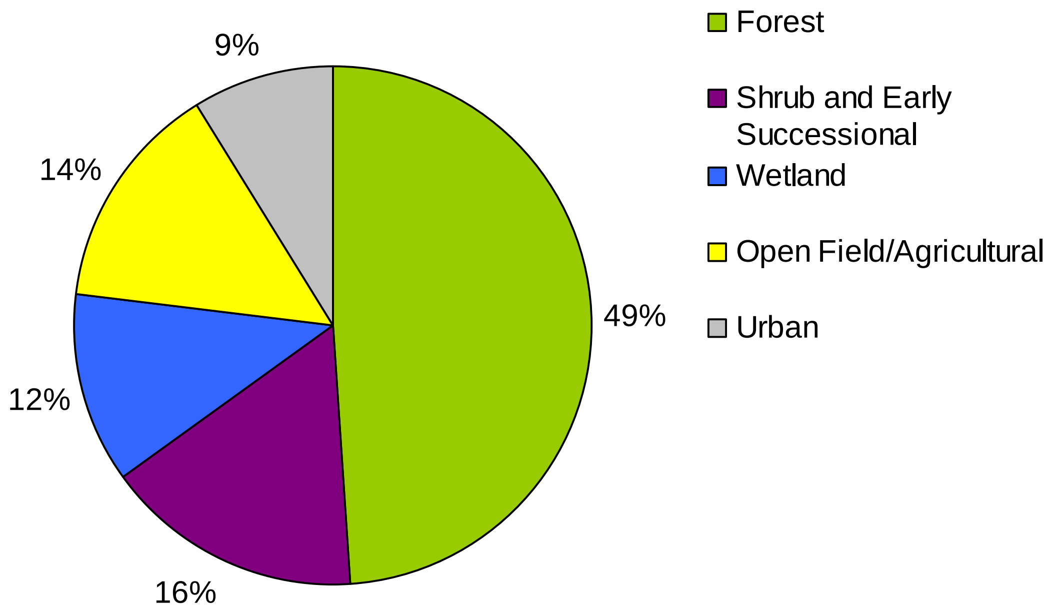


Figure 4. Bird species detected between 2002 and 2008 in the Credit River Watershed, grouped by habitat preference.

In 2004 Credit Valley Conservation Authority ranked species inhabiting the watershed according to their sensitivity to environmental change and disturbance. According to a draft version of the ranking, a total of 110 species in the Credit River Watershed have been designated as Species of Conservation Concern (SoCC). These species are designated at risk either federally and/or provincially, or are provincially rare according to OMNR's Natural Heritage Information Centre. Species of Interest (SoI) are either uncommon in the watershed and/or have exhibited a significant population decline in the past 25 years. Species of Urban Interest (SoUI) overwinter in the Credit River Watershed but breed elsewhere, are area sensitive or forest interior nesting species. Based on the draft version of the list (2009), over two-thirds of bird species detected in the Watershed fall within one of the three concern categories (SoCC, SoI and SoUI; Table 4). The remaining species are considered to be stable or non-native.

Table 4. Ranking of Bird Species Detected in the Watershed by the Terrestrial Monitoring Program, according to CVC's Species of Conservation Concern.

Species of Conservation Concern Ranking	Number of Bird Species
Species of Conservation Concern	4
Species of Interest	35
Species of Urban Interest	44
Secure	26
Non-native	5

3.1.2 Most Common Species

Monitoring Question: What were the 10 most common forest bird species encountered in the Credit River Watershed?

All of the top 10 species (Table 5) are widespread across the province, four of which are considered to be Habitat Generalists (Black-capped Chickadee, American Crow, American Robin and Northern Cardinal; Appendix C). Five of the top ten species are also considered to be regular urban inhabitants (Black-capped Chickadee, Blue Jay, American Crow, American Robin and Northern Cardinal) by the Ontario Breeding Bird Atlas (Cadman et al. 2008). The high abundance of urban tolerant, generalist species in forest plots reflects the presence of non-forest communities and land-uses throughout the Credit Watershed. The forest bird community observed in the Watershed is what would be expected in deciduous forests of southern Ontario.

Table 5. Ten most widespread forest bird species in the Credit River Watershed, between 2002 and 2008.

Species Common Name	Species Latin Name	Frequency of detections [a]	Relative Abundance [b]
Red-eyed Vireo	*Vireo olivaceus*	24.1	153.0
Black-capped Chickadee	*Poecile atricapillus*	23.8	100.9
American Crow	*Corvus brachyrhynchos*	19.2	99.9
American Robin	*Turdus migratorius*	23.4	79.7
Ovenbird	*Seiurus aurocapillus*	12.4	68.7
Blue Jay	*Cyanocitta cristata*	22.9	62.6
Eastern Wood-pewee	*Contopus virens*	22.6	59.6
Great Crested Flycatcher	*Myiarchus crinitus*	17.9	38.7
Northern Cardinal	*Cardinalis cardinalis*	12.6	37.4
Wood Thrush	*Hylocichla mustelina*	10.7	26.3

[a] The average number of sites (out of a total of 25) that a species was detected, across years.
[b] The average abundance, Watershed-wide, across years.

3.1.3 Community Composition

Monitoring Question: Did species composition change over the monitoring period?

- Species turnover in the monitored sites ranged between 29% and 20% between years.

Jaccard Similarity Values ranged between 0.71 and 0.80 representing a 29 to 20 percent annual turnover rate in species composition. Although not significant, the greatest turnover in species composition occurred between 2004 and 2005 (29% species turnover), with communities exhibiting the greatest similarity between 2003 and 2004 (20% turnover; Fig 5, Table 6).

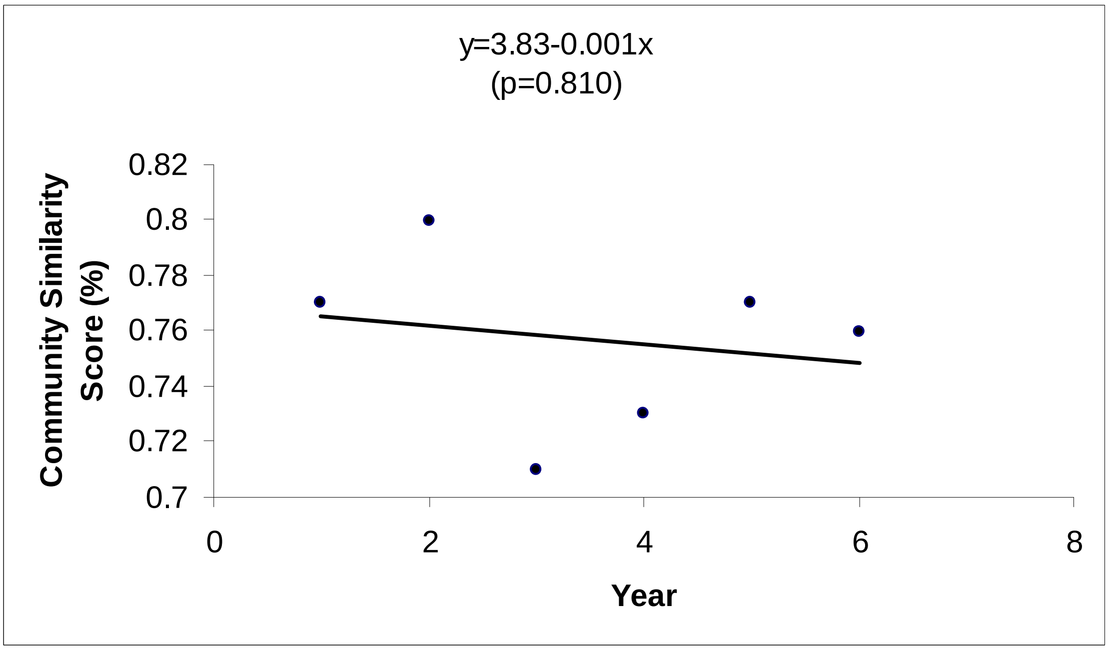


Figure 5. Community Similarity at 25 forest plots in the Credit River Watershed between 2002 and 2008. Equation of the regression line and p value provided. Community Similarity remained stable between 2002 and 2008.

Table 6. Percent community similarity and dissimilarity for forest bird species, Watershed-wide, between years.

Comparison	% Community Similarity	% Community Dissimilarity
2002-2003	0.77	0.23
2003-2004	0.80	0.20
2004-2005	0.71	0.29
2005-2006	0.73	0.27
2006-2007	0.77	0.23
2007-2008	0.76	0.24

3.2 TEMPORAL ANALYSIS

3.2.1 Species Richness and Diversity

Monitoring Question: Is forest bird species richness and diversity changing in the Credit River Watershed?

- Forest bird species richness increased in the Watershed between 2002 and 2008.
- Forest bird species diversity was stable in the Watershed between 2002 and 2008.

According to the Linear Regression Trend Analysis, bird species richness showed an increasing trend between 2002 and 2008 in the Credit River Watershed (β=0.06, F=6.875, p =0.046; Table 7, Fig. 6). Bird species diversity and community similarity were stable between 2002 and 2008 in the Credit River Watershed (β=-0.004, F=0.792, p =0.410 and β=-0.001, F=0.069, p =0.810, respectively; Table 7, Fig. 7 & 8). Statistical Process Control IMR Charts were 'in control', indicating a stable time series upon which thresholds could be established (Tables 7 & 8). The slow and steady increase in species richness was not large enough to create 'out of control' non-random fluctuations in the SPC IMR Charts.

Table 7. Community Metric Trends and Statistical Process Control Results.

Community Metric	Average Annual Rate of Change (β)	*F* value	*p*-Value	R^2	Observed Trend	Statistical Process Control [b]
Species Richness						
Watershed-wide	0.060	**6.875**	**0.046**	**0.494**	**increasing**	in control
Lower Watershed	1.035	1.854	0.123	0.289	stable	in control
Middle Watershed	0.250	0.540	0.612	0.134	stable	in control
Upper Watershed	-0.107	-0.253	0.810	-0.185	stable	in control
Species Diversity						
Watershed-wide	-0.004	0.792	0.410	-0.036	stable	in control
Lower Watershed	-0.014	-0.602	0.573	-0.119	stable	in control
Middle Watershed	-0.043	-1.780	0.135	0.266	stable	in control
Upper Watershed	-0.058	**-2.124**	**0.087**	**0.369**	**declining trend**	in control
Total Abundance [a]						
Watershed-wide	0.032	**5.319**	**<0.0001**	**n/a**	**increasing**	in control
Lower Watershed	0.042	**4.056**	**<0.0001**	**n/a**	**increasing**	in control
Middle Watershed	0.032	**3.795**	**<0.0001**	**n/a**	**increasing**	in control
Upper Watershed	0.018	**2.033**	**0.042**	**n/a**	**increasing**	in control

[a] z values calculated for parameters analysed with Poisson Regression
[b] Both the Individuals and Moving Average Charts were 'in control' to be labelled as such. Species richness was the only community metric that showed a changing trend between 2002 and 2008.

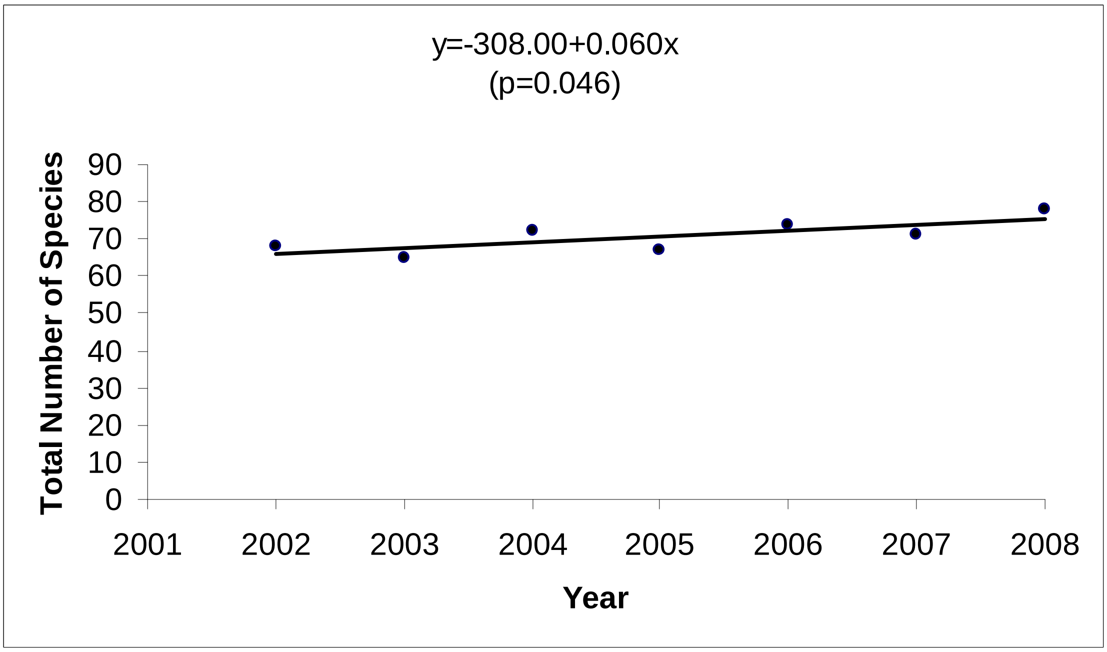


Figure 6. Total number of forest bird species observed at 25 forest plots in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p* value provided. Species richness increased 6% per year between 2002 and 2008

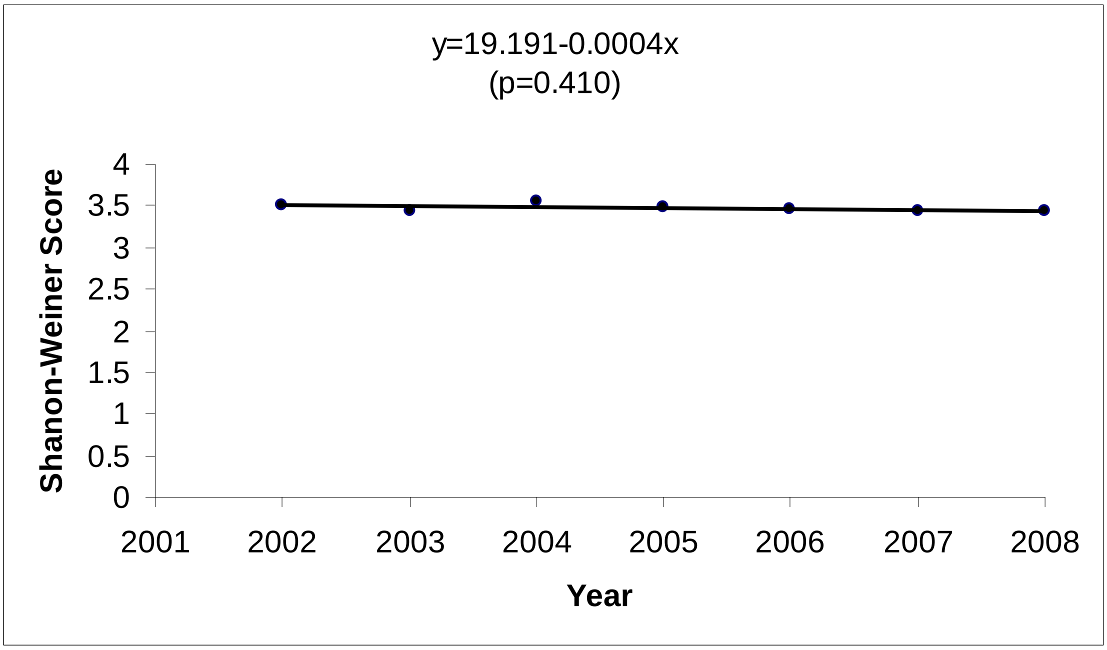


Figure 7. Total species diversity at 25 forest plots in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p* value provided. Species Diversity remained stable between 2002 and 2008.

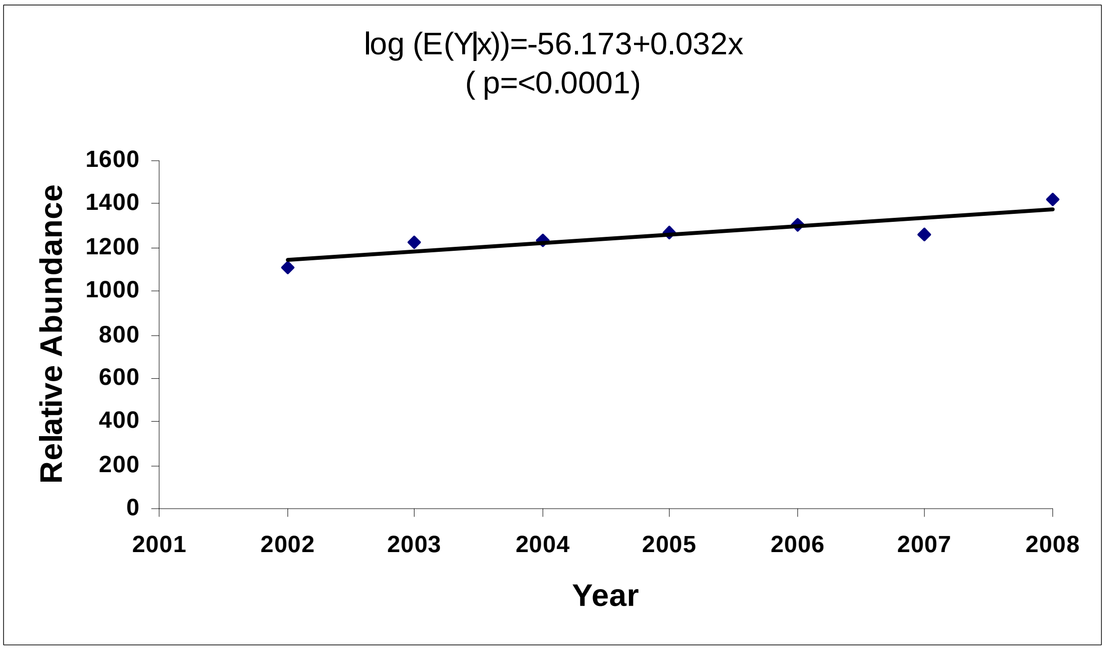


Figure 8. Total number of forest birds detected at 25 forest plots in the Credit River Watershed between 2002 and 2008. Average annual rate of change and *p*-value provided in parentheses. Total abundance remained stable between 2002 and 2008.

Table 8. Monitoring thresholds extracted from Statistical Process Control Individuals (Moving Average) IMR Charts representing data collected between 2002 and 2008.

	Thresholds			
Parameter	**Upper Critical Threshold**	**Upper Warning Threshold**	**Lower Critical threshold**	**Lower Warning Threshold**
Community Metrics				
Species Richness	84.9	75.4	56.5	61.3
Species Diversity	3.6	3.5	3.3	3.4
Community Similarity	0.86	0.82	0.66	0.70
Total Abundance	1571.4	1380.5	998.6	1094.0
Guild Abundance				
Resident Species	690.6	628.6	318.2	380.3
Short-Distance Migrants	783.0	697.7	271.3	356.6
Long-Distance Migrants	901.2	845.4	551.3	610.1
Forest Associates	1092.0	1020.3	662.0	733.7
Habitat Generalists	889.8	817.2	457.1	529.2
Edge/Early Successional Species	138.8	130.4	88.3	96.7
Ground Nesting Species	264.1	246.2	156.8	174.8
Shrub Nesting Species	637.8	565.8	205.9	277.9
Sub-Canopy/Canopy Nesting Species	1064.3	965.9	474.6	572.9
Cavity Nesting Species	397.9	369.2	225.9	254.5
Aerial Foragers	176.2	162.8	95.5	109.0

Watershed-wide, a total of 65 to 78 forest bird species were detected annually. Species richness was lowest in 2003 and highest in 2008. It is not clear why species richness increased in the Credit River Watershed since monitoring began. Bird surveys were conducted by the same individuals from 2003 onwards, reducing the potential for observer bias. A greater number of species at risk were detected in 2008 than any other year, but this does not explain the steady increase observed throughout the whole monitoring period (Table 7). Changes in bird abundance and species composition occur due to processes both in the breeding and wintering grounds (for migratory species). Changes in habitat suitability due to anthropogenic alteration or natural successional processes are likely to influence species composition as do events that change food availability, such as the introduction of bird feeders in urban and sub-urban areas, or insect outbreaks in areas with higher forest composition (Holmes and Sherry 2001). Extreme weather events both in the breeding and overwintering habitats can also have both positive and negative effects on bird species composition, over the short and long-terms (Holmes and Sherry 2001). It is also hypothesized that climate change has the potential to change species richness as bird species associated with more southern regions expand northwards, and more northern species contract further north to accommodate for the changes in vegetation composition and structure that are expected to occur. Further monitoring of species richness will provide more insight into the mechanism behind increasing species richness in the Credit River Watershed.

Watershed-wide, species diversity ranged between 3.43 and 3.55 annually. It was lowest in 2008 and highest in 2004, although not significantly. It is important to note that although species richness showed an increasing trend, that species diversity remained stable. Because species diversity accounts for relative abundance of all species detected, the non-significant results are likely a function of the fact that newly detected species were only represented by one or two individuals (Table 7, see discussion on total relative abundance below).

3.2.2 Species Relative Abundance

Monitoring Question: Is forest bird relative abundance changing in the Credit River Watershed?

- Forest bird relative abundance increased in the Watershed between 2002 and 2008.

Watershed-wide, forest bird relative abundance increased between 2002 and 2008 in the Credit River Watershed (β=0.032, z=-5.319, p <0.0001; Table 7, Fig.8). Relative abundance was lowest in 2002 with 1109 individuals detected, relative to 2008 when 1418 individual birds were observed Watershed-wide.

Holmes and Sherry (2001) suggest that large changes in bird abundance and species composition can occur over time even in undisturbed and relatively mature habitats due to natural successional processes changing vegetation structure and increases in summer food availability due to insect outbreaks.

Statistical Process Control IMR Charts were ‘in control’, indicating a stable time series upon which thresholds could be established (Tables 4 & 5).

3.2.3 Bird Guild Relative Abundance

Monitoring Question: Are any forest bird guilds changing in relative abundance in the Credit River Watershed?

- Watershed-wide, populations of Residents, Short-distance Migrants, Long-distance Migrants, Habitat Generalists and Canopy/Sub-canopy Nesting Species showed increasing trends. Cavity-Nesting and Shrub Nesting bird species also showed increasing trends towards significance between 2002 and 2008.
- Populations of Long-Distance Migrants did not increase, while Shrub Nesting and Edge/Early Successional Species increased in the Lower Watershed.
- Habitat Generalists, Edge/Early Successional and Ground Nesting Species have declined in the Middle Watershed.
- Ground Nesting Species also declined in the Upper Watershed Zone.

According to the Poisson Regression Trend Analyses, populations of Residents (β=0.089,z=7.319, p <0.0001), Short-distance Migrants (β=0.038,z=3.536, p =0.0004), Long-distance Migrants (β=0.052,z=5.430, p <0.0001), Habitat Generalists (β=0.028,z=3.061, p =0.002) and Canopy/Sub-canopy Nesting Species (β=0.050,z=5.040, p <0.0001) all showed increasing trends between 2002 and 2008 watershed-wide (Table 7, Appendix F). Over the same time period, populations of Cavity Nesting Species β=0.026, z=1.920, p =0.055) and Shrub Nesting Species showed trends towards increasing Watershed-wide (β=0.018, z=1.757, p =0.079; Table 9, Appendix F). Populations of the remaining four guilds were statistically stable throughout the same time period. Statistical Process Control IMR Charts were 'in control', indicating a stable time series upon which thresholds could be established (Tables 8 & 9).

When population trends of guilds were analyzed separately for each of the three Physiographic Zones, some differences were detected. Contrary to Watershed-wide trends, Long-distance Migrants (β=-0.010, z=-0.932, p =0.352) did not increase in the Lower Watershed between 2002 and 2008, but Shrub Nesting Species (β=0.049, z=3.398, p <0.0001) and Edge/Early Successional Species (β=0.011, z=1.986, p =0.046) did show increasing trends over the monitoring period. Habitat Generalists (β=-0.037, z=-3.235, p =0.001), Edge/Early Successional Species (β=0.012, z=-1.973, p =0.004) and Ground Nesting Species showed declining population trends in the Middle Watershed (β=-0.054, z=-2.705, p =0.006) that were not detected Watershed-wide. Short-distance Migrants were also stable in the Middle Watershed between 2002 and 2008 (β=0.006, z=0.444, p =0.657). Similar to the Middle Watershed, populations of Ground Nesting Species declined between 2002 and 2008 (β=-0.072, z=-3.654, p =0.00013), while Short-Distance Migrants remained stable (β=-0.003, z=-0.181, p =0.856). Additionally, unlike Watershed-wide trends, Habitat Generalists remained stable in the Upper Watershed (β=-0.0008, z=-30.055, p =0.956).

Table 9. Forest Bird Guild Population Trends and Statistical Process Control Results**.**

Guild	Average Annual Rate of Change	*Z* Value	*p*-Value	Observed Trend [a]	Statistical Process Control [b]
Migratory Guild					
Resident Bird Species					
Watershed-wide	0.089	**7.319**	**<0.0001**	**increasing**	in control
Lower Watershed	0.037	**2.744**	**0.006**	**increasing**	in control
Middle Watershed	0.003	0.166	0.868	stable	in control
Upper Watershed	-0.011	-0.754	0.451	stable	in control
Short-Distance Migrants					
Watershed-wide	0.038	**3.536**	**0.0004**	**increasing**	in control
Lower Watershed	0.028	**2.155**	**0.031**	**increasing**	in control
Middle Watershed	0.006	0.444	0.657	stable	in control
Upper Watershed	-0.003	-0.181	0.856	stable	in control
Long-Distance Migrants					
Watershed-wide	0.052	**5.430**	**<0.0001**	**increasing**	in control
Lower Watershed	-0.010	-0.932	0.352	stable	in control
Middle Watershed	0.013	**2.001**	**0.031**	**increasing**	in control
Upper Watershed	0.090	**2.384**	**0.017**	**increasing**	in control
General Habitat Association Guilds					
Forest Associates					
Watershed-wide	-0.005	-0.594	0.552	stable	in control
Lower Watershed	-0.004	-0.242	0.809	stable	in control
Middle Watershed	0.015	1.481	0.138	stable	in control
Upper Watershed	-0.006	-0.615	0.539	stable	in control
Habitat Generalists					
Watershed-wide	0.028	**3.061**	**0.002**	**increasing**	in control
Lower Watershed	0.011	0.873	0.383	stable	in control
Middle Watershed	-0.037	**-3.235**	**0.001**	**declining**	in control
Upper Watershed	-0.00008	-0.055	0.956	stable	in control
Edge/Early Successional Species					
Watershed-wide	-0.001	-0.043	0.966	stable	in control
Lower Watershed	0.011	**1.986**	**0.046**	**increasing**	in control
Middle Watershed	-0.062	**-1.973**	**0.049**	**declining**	in control
Upper Watershed	-0.123	**-2.834**	**0.005**	**declining**	in control
Nesting Guilds					
Ground Nesting Species					
Watershed-wide	0.040	0.775	0.438	stable	in control
Lower Watershed	-0.0006	-0.036	0.971	stable	in control
Middle Watershed	-0.053	**-2.705**	**0.007**	**declining**	in control
Upper Watershed	-0.072	**-3.654**	**0.0003**	**declining**	in control
Shrub Nesting Species					
Watershed-wide	0.018	**1.757**	**0.079**	**increasing trend**	in control
Lower Watershed	0.049	**3.398**	**0.0007**	**increasing**	in control
Shrub Nesting Species					
Middle Watershed	-0.015	-0.972	0.331	stable	in control
Upper Watershed	-0.006	-0.300	0.764	stable	in control

Guild	Average Annual Rate of Change	*Z* Value	*p*-Value	Observed Trend [a]	Statistical Process Control [b]
Nesting Guilds (Cont'd)					
Canopy-Sub/Canopy Species					
Watershed-wide	0.050	**5.040**	**<0.0001**	**increasing**	in control
Lower Watershed	-0.020	-1.246	0.213	stable	in control
Middle Watershed	0.009	0.887	0.375	stable	in control
Upper Watershed	0.005	0.479	0.632	stable	in control
Cavity Nesting Species					
Watershed-wide	0.026	**1.920**	**0.055**	**increasing trend**	in control
Lower Watershed	0.018	0.964	0.335	stable	in control
Middle Watershed	-0.020	-1.126	0.260	stable	in control
Upper Watershed	-0.002	-0.115	0.908	stable	in control
Foraging Guild					
Aerial Foragers					
Watershed-wide	0.027	1.275	0.202	stable	in control
Lower Watershed	-0.055	-1.554	0.120	stable	in control
Middle Watershed	0.036	1.413	0.158	stable	in control
Upper Watershed	0.008	0.317	0.752	stable	in control

[a] Resident Bird Species showed increasing trends, while Ground Nesting Species showed declining trends watershed-wide between 2002 and 2008.
[b] Both the Individuals and Moving Average Charts were 'in control' to be labelled as such.

Resident bird species showed increasing population trends Watershed-wide. This was consistent with trends reported in the Ontario breeding Bird Atlas (Cadman et al. 2008), which were attributed to milder winters and increasing forest cover in regions of Ontario. The increase in Short-distance Migrants, primarily in the Lower Watershed, was also supported by province-wide trends observed in the Ontario Breeding Bird Atlas (Cadman et al. 2002) and nation-wide in the Canadian Breeding Bird Survey (Downes and Collins 1996). Many Short-distance Migrants are seed-eating, grassland or shrub nesting species, and increasing populations may be attributed to increased availability of habitats these species are dependent upon in the Lower Watershed (i.e. abandoned agriculture reverting back to meadow, and shrub thickets associated with forest edge habitats prevalent in urbanized areas; Cadman et al. 2008).

Increasing populations of Long-Distance Migrants in the Credit River Watershed between 2002 and 2008 were unexpected as the Ontario Breeding Bird Atlas (Cadman et al. 2008) has reported an overall decrease in Long-Distance Migrants in the Carolinian and Lake Simcoe Regions. On a national scale, the Canadian Breeding Bird Survey has also reported significant long-term declines in populations of Neotropical Migrants between 1967 and 2000. It is important to note that the observed population increases are driven by processes in the Middle and Upper Watersheds alone, as this trend was not observed in the Lower Watershed. It is possible that maturation and restoration of forest habitats in these two Physiographic Zones since 2002 have provided more favourable conditions for Long-Distance Migrants. Holmes and Sherry (2001) suggest that large changes in bird abundance and species composition can occur over time even in undisturbed and relatively mature habitats due to natural successional processes changing vegetation structure and increases in summer food availability due to insect outbreaks. It is also important to note that the decline of Long-distance Migrants reported by the Ontario Breeding Bird Atlas (Cadman et al. 2008) is heavily influenced by the inclusion of aerial foraging swallow and nightjar species, which are one of the groups undergoing the most severe population declines continent-wide. The absence of these species in Credit Watershed forests may partially account for differences in observed trends. Further monitoring will allow us to determine whether this trend will continue in the Credit Watershed over the long-term, or whether it is just a temporary response to some undefined process(es).

Increasing populations of Habitat Generalists and Shrub Nesting Species are driven primarily by processes in the Lower Watershed. The increasing populations of Edge/Early Successional Species in the Lower Watershed combined with those observed with Habitat Generalists and Shrub Nesting Species are likely related to the increasing fragmentation and urbanization of the Lower Physiographic Zone, as urban development generally increases the availability of edge and shrub dominated habitats (Marzluff 1997). Most of the species belonging to these three guilds are urban tolerant and require periodic disturbance to regulate and create essential nesting habitat conditions. The Ontario Breeding Bird Atlas (Cadman et al. 2008) has also reported a significant increase in urban tolerant, generalist species Ontario-wide. However, Edge/Early Successional and Shrub species were reported to decline in the Carolinian and Lake Simcoe-Rideau Regions, due to agricultural intensification. Intensification of urban development, rather than agriculture has been observed in the Lower Watershed, which explains the different trends observed in our study relative to the Ontario Breeding Bird Atlas (Cadman et al. 2008).

It is interesting to note that declines of Ground Nesting Species were only observed in the Middle and Upper Watersheds. The lack of declining trends observed for this guild in the Lower Watershed are likely due to their relatively low abundance in the Lower Physiographic Zone. Of special note is that declines of Ground Nesting Species were more severe in the Upper than the Middle Watershed. This difference may be attributed to the higher proportion of agricultural land in the Upper Watershed. Many nest predators such as domestic cats, eastern grey squirrels, racoons, blackbirds, and corvids (e.g. American Crow, Blue Jay) and brood parasites are generally more abundant in agricultural than forested landscapes, with the potential to increase levels of nest predation and parasitism in agricultural matrices (Angelstam 1986; Burke and Nol 2000; Rodewald and Yahner 2001). Ground Nesting bird species suffer from higher nest predation rates than shrub or canopy nesting species (Martin 1993), making them especially sensitive to changes in nest predator species composition and abundance. Analysis of land-use change in the Credit Watershed will provide insight into whether nest predator communities have changed between 2002 and 2008, and whether this is a likely explanation for the declining population trends observed in this sensitive nesting guild.

The trend towards increasing populations of Cavity Nesting Bird Species is supported by province-wide trends (Cadman et al. 2008). Most Cavity Nesting Bird Species are residents to southern Ontario, and are therefore likely responding positively to milder winter temperatures and increasing forest cover values in certain regions. Many species are also regular visitors to bird feeders, so increasing popularity of these supplemental food sources are likely contributors to the observed increases. Of special note is that the increasing trend is heavily influenced by increased observations of Red-bellied Woodpecker detections, whose probability of observation increased by 200% province-wide since the last Breeding Bird Atlas (Cadman et al. 2008).

3.2.4 Individual Bird Species Relative Abundance

Monitoring Question: Are any individual forest bird species changing in relative abundance in the Credit River Watershed?

- Populations of 8 forest bird species have increased in the Watershed between 2002 and 2008.
- Populations of 2 forest bird species have decreased in the Watershed between 2002 and 2008.

According to the Poisson Regression Trend Analyses conducted, populations of eight forest bird species, American Robin (β=0.083, p <0.001), Black-capped Chickadee (β=0.039, p =0.035), Brown-headed Cowbird *(Molothrus ater*; β=0.169, p =0.002), Black-throated Green Warbler *(Dendroica virens*; β=0.078, p =0.044), Cedar Waxwing *(Bombycilla cedrorum*; β=0.093, p =0.028), Eastern Wood-pewee (β=0.046, p =0.061), House Wren *(Troglodytes aedon*; β=0.111, p =0.074), and Red-eyed Vireo (β=0.081, p <0.001) showed increasing trends between 2002 and 2008, watershed-wide (Table 7, Appendix G). Northern Flicker (β=-0.071, p =0.071) and Ovenbird *(Seiurus aurocapillus*; β=-0.037, p =0.081) showed declining trends at the P <0.10 level, and must be monitored closely in the future. Populations of the remaining 17 species were however stable throughout the same time period. Statistical Process Control IMR Charts were 'in control', for all but two species, Chipping Sparrow *(Spizella passerina)* and Red-eyed Vireo. For species with 'in-control' time series, thresholds were established using the complete 2002 to 2008 dataset. For the remaining two species, thresholds were calculated for only the 'in-control' years (Tables 9, 10 & 11; Appendix G).

When species population trends were analyzed separately for each of the three Physiographic Zones, some differences were detected. In the Middle Watershed, both Blue Jay (β=0.079, p =0.033) and Eastern Wood-pewee (β=0.103, p =0.007) showed increasing population trends. American Crow populations also showed increasing trends (β=0.061, p =0.050) in the Upper Watershed between 2002 and 2008.

With the exception of Brown-headed Cowbird and Eastern-wood Pewee, all individual species population trends observed in the Credit River Watershed were consistent with those observed by the Canadian Breeding Bird Survey (Downes and Collins 1996). Brown-headed Cowbird densities are influenced by the availability of high quality foraging areas and breeding opportunities in a landscape (Lowther 1993). Preferred foraging habitats include open fields, crop and pasture lands where cowbirds consume seeds and insects (Lowther 1993). Often associated with forest edges, cowbirds obtain their highest densities in landscapes fragmented by agriculture (Lowther 1993). Properties in the Upper Watershed have been farmed less intensively in the recent past (Sparling et al. 2008), which has allowed the natural succession of row crops to meadow and shrub habitats; ideal conditions for this brood parasite. Increasing populations of the Brown-headed Cowbird in the Credit River Watershed are therefore not surprising, despite the declines observed province and nation-wide by Ontario Breeding Bird Atlas (Cadman et al. 2008) and Canadian Breed Bird Survey (Downes and Collins 1996). The increasing trend of Eastern Wood-pewee populations in the Middle Watershed is contrary to the declines observed province-wide (Downes and Collins 1996; Cadman et al. 2008). Further monitoring is required to determine whether this is a temporary occurrence, or a long-term trend that reflects land-use and habitat availability in the Middle Watershed.

Table 10. Population Trends and Statistical Process Control Results for 28 forest bird species monitored between 2002 and 2008 in the Credit River Watershed

Bird Species	Average Annual Rate of Change	*Z* Value	*p*-Value	Observed Trend [b]	Statistical Process Control [c]
American Crow	0.005	0.246	0.806	stable	in control
American Robin	0.083	**3.884**	**<0.0001**	**increase**	in control
Black-capped Chickadee	0.039	**2.087**	**0.037**	**increase**	in control
Brown-headed Cowbird	0.169	**3.090**	**0.002**	**increase**	in control
Blue Jay	0.028	1.170	0.242	stable	in control
Black-throated Green Warbler	0.078	**2.027**	**0.043**	**increase**	in control
Cedar Waxwing	0.093	**2.208**	**0.027**	**increase**	in control
Chipping Sparrow	0.050	0.942	0.346	stable	out of control
Common Grackle	-0.028	-0.724	0.469	stable	in control
Downy Woodpecker	0.025	0.589	0.556	stable	in control
Eastern Wood-pewee [a]	0.046	**1.884**	**0.060**	**increase**	in control
Great Crested Flycatcher	0.006	0.213	0.832	stable	in control
Hairy Woodpecker	0.080	1.543	0.123	stable	in control
House Wren [a]	0.111	**1.810**	**0.070**	**increase**	in control
Indigo Bunting	0.031	0.721	0.471	stable	in control
Northern Cardinal	0.024	0.772	0.440	stable	in control
Northern Flicker [a]	-0.071	**-1.632**	**0.071**	**decrease**	in control
Ovenbird [a]	-0.037	**-1.618**	**0.081**	**decrease**	in control
Pine Warbler	0.061	1.045	0.296	stable	in control
Rose-breasted Grosbeak	-0.002	-0.052	0.959	stable	in control
Red-eyed Vireo	0.081	**5.257**	**<0.0001**	**increase**	out of control
Scarlet Tanager	0.038	0.780	0.435	stable	in control
Song Sparrow	-0.033	-1.071	0.284	stable	in control
Veery	0.109	0.626	0.800	stable	in control
White-breasted Nuthatch	0.038	0.935	0.350	stable	in control
Winter Wren	0.039	1.068	0.285	stable	in control
Wood Thrush	0.068	1.252	0.210	stable	in control

[a] Species showing trends approaching significance.
[b] Eight species showed significant increasing trends, and four species exhibited significant declining trends Watershed-wide.
[c] Both the Individuals and Moving Average Charts were 'in control' to be labelled as such.

It is not surprising that urban tolerant species such as the American Robin, Black-capped Chickadee and House Wren increased as the area between Niagara and Toronto has shown a general decline in forest cover due to urbanization over the last 20 years (Cadman et al. 2008). Population increases of these three species are driven by processes in the Lower Watershed, where increases were the strongest. Species that are able to exploit urban environments are capable of reaching dense and stable populations in urban and suburban areas because of moderated climate, increased food and water availability, the reduction in forest associated predators and the introduction of new and safer artificial nest sites (Marzluff 2001). Increasing populations of American Robin and Black-capped Chickadee were also reported in the Ontario Breeding Bird Atlas (Cadman et al. 2008). Cedar Waxwing population trends were driven by process in the Lower Watershed, such as the creation of shrub and early successional habitats associated with urbanization.

Table 11. Monitoring thresholds extracted from Statistical Process Control Individuals (Moving Average) IMR Charts representing data collected between 2002 and 2008.

Parameter	Thresholds			
	Upper Critical Threshold	Upper Warning Threshold	Lower Critical threshold	Lower Warning Threshold
American Crow	134.4	122.9	65.3	76.8
American Robin	125.4	110.2	34.1	49.3
Black-capped Chickadee	161.2	141.1	40.6	60.7
Brown-headed Cowbird	23.8	20.1	1.6	5.4
Blue Jay	85.2	77.6	40.0	47.5
Black-throated Green Warbler	39.4	34.3	9.2	14.2
Cedar Waxwing	39.0	32.8	0.0	8.0
Chipping Sparrow [a]	17.5	16.5	11.1	12.2
Common Grackle	55.6	45.3	0.0	3.9
Downy Woodpecker	25.5	23.7	14.8	16.6
Eastern Wood-Pewee	75.5	70.2	43.6	48.9
Great Crested Flycatcher	56.0	50.2	21.4	27.2
Hairy Woodpecker	25.4	21.4	1.5	5.4
House Wren	25.2	20.1	0.0	4.5
Indigo bunting	37.1	31.4	2.6	8.3
Northern Cardinal	49.4	45.4	25.5	29.4
Northern Flicker	30.8	27.0	7.8	11.6
Ovenbird	89.1	82.3	48.3	55.1
Pine Warbler	29.2	23.0	0.0	1.7
Rose-breasted Grosbeak	25.7	21.6	0.9	5.0
Red-eyed Vireo [a]	178.3	169.8	127.7	136.2
Scarlet Tanager	27.4	23.3	2.6	6.7
Song Sparrow	58.1	51.4	18.2	24.8
Veery	32.1	28.4	9.9	13.6
White-breasted Nuthatch	35.3	30.7	7.8	12.4
Winter Wren	26.6	21.8	0.0	2.2
Wood Thrush	42.2	37.0	10.3	15.7

[a] Thresholds were calculated for 'in-control' period only. Chipping Sparrow had 6 years of 'in-control' data, Red-eyed Vireo had 5 years of 'in-control' data.

Population increases of the Red-eyed Vireo, Black-throated Green Warbler, American Crow and Blue Jay have also been reported by the Canadian Breeding Bird Survey and Ontario Breeding Bird Atlas (Downes and Collins 1996; Cadman et al. 2008). Although it is unclear why Red-eyed Vireo populations are increasing nationwide, the conversion of extensive coniferous plantations to deciduous forest is a possible explanation (Cadman et al. 2008). The maturation of forests on abandoned farmland and maturation of conifer plantations in Ontario is suspected to have contributed to observed increasing populations of the Black-throated Green Warbler province-wide (Cadman et al. 2008). American Crows spend most of their time feeding in open habitats such as agricultural fields (Marzluff et al. 2001; Verbeek and Caffrey 2002). Increasing populations in Ontario have been attributed to intensification of agriculture and higher road traffic volumes which provide crows with a staple in their diets: road kill (Cadman et al. 2008). This is consistent with increasing populations only observed in the more agricultural Upper Watershed. Although considered a habitat generalist that is often abundant in urban areas, the Blue Jay has much lower densities in areas where forest cover is heavily diminished due to urban or agricultural intensification, unless suitable woodland patches are still available for nesting and foraging (Cadman et al. 2008). Blue Jay populations were observed to only increase in the Middle Watershed, which is likely due to increased forest cover in the zone since 2002. These trends are consistent with observations reported province and nation-wide for the species.

Declines of two species in the Credit Watershed, the Ovenbird and Northern Flicker, are of particular concern. Significant declines of both species have been reported both nation and province-wide (Downes and Collins 1996; Cadman et al. 2008). The Ovenbird is a ground-nesting, area-sensitive, mature forest specialist (Van Horn and Donovan 1994; Holmes and Sherry 2001) that is common and widespread throughout Ontario (Cadman et al. 2008). Loss of overall forest cover, mature forest habitat and fragmentation of remaining woodlots in Ontario are likely explanations for its observed decline (VanHorn and Donovan 1994; Cadman et al. 2008). Also a common and widespread species, the Northern Flicker has been declining continent-wide since 1966 (Wiebe and Moore 2008; Cadman et al. 2008). Declines have been attributed to loss of appropriate nesting substrates (large diameter snags or declining trees) and competition with hole-nesting species such as the non-native European Starling (Wiebe and Moore 2008). Although not yet listed as a species of special concern, significant population declines of this species continent-wide would have serious implications for a diversity of species that rely on the flicker as a keystone cavity-provider (Martin et al. 2004; Wiebe and Moore 2008). Further monitoring will determine whether both these species continue to decline in the Credit River Watershed, and whether intervention will be required to maintain populations of these currently widespread and common species.

3.2.5 Power Analysis and Statistical Process Control

Power analysis was completed for all forest bird parameters that were in control (Tables 6, 8 & 9). According to power analysis 45, 11 and 5 sites would be needed in order to detect 1, 2 and 3 SD of change, respectively, over seven monitoring years for all forest bird parameters analyzed using linear regression analysis (i.e. bird species richness, species diversity and community similarity). For forest bird parameters that were analyzed with poisson regression (i.e. total abundance, guild abundances and individual species abundances), 7, 2 and 1 sites would be needed in order to detect 1, 2 and 3 SD of change, respectively, over seven monitoring years. Therefore, a sufficient number of sites were monitored to detect significant changes in the forest bird 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 will be used as a warning threshold in statistical process control and changes in the magnitude of 3 SD will be used as the critical threshold. Detectable effect size for forest bird parameters were all ranked as "Green" (Tables 12 &13). This means that the data quality are good according to the standards applied by Dobbie et al. (2006).

Table 12. Power analysis results for detecting effect sizes for Trend Analyses for community metrics and guild abundances.

Parameter	Minimum Detectable Percent Change (%) [a]	Data Quality
Community Metrics		
Species Richness	1.20	Green
Species Diversity	2.91	Green
Community Similarity	3.12	Green
Total Abundance	1.23	Green
Guild Abundance		
Migratory Guilds		
Resident Species	1.96	Green
Short-Distance Migrants	1.85	Green
Long-Distance Migrants	1.66	Green
General Habitat Association Guilds		
Forest Associates	1.47	Green
Habitat Generalists	1.62	Green
Edge/Early Successional Species	4.23	Green
Nesting Guilds		
Ground Nesting Species	3.27	Green
Shrub Nesting Species	2.15	Green
Sub-Canopy/Canopy Nesting Species	1.56	Green
Cavity Nesting Species	2.44	Green
Foraging Guild		
Aerial Foragers	3.68	Green

[a] Values represent the minimum effect size detectable under current monitoring conditions.

Table 13. Power analysis results for detecting effect sizes for Trend Analyses for individual species abundances.

Parameter	**Minimum Detectable Percent Change (%)** [a]	**Data Quality**
American Crow	4.22	Green
American Robin	4.71	Green
Black-capped Chickadee	4.28	Green
Brown-headed Cowbird	14.19	Green
Blue Jay	5.46	Green
Black-throated Green Warbler	8.62	Green
Cedar Waxwing	4.03	Green
Chipping Sparrow	12.18	Green
Common Grackle	8.66	Green
Downy Woodpecker	9.54	Green
Eastern Wood-Pewee	5.59	Green
Great Crested Flycatcher	6.84	Green
Hairy Woodpecker	10.16	Green
House Wren	13.37	Green
Indigo bunting	9.52	Green
Northern Cardinal	6.98	Green
Northern Flicker	9.71	Green
Ovenbird	5.13	Green
Pine Warbler	1.31	Green
Rose-breasted Grosbeak	12.17	Green
Red-eyed Vireo	3.42	Green
Scarlet Tanager	11.11	Green
Song Sparrow	6.97	Green
Veery	9.34	Green
White-breasted Nuthatch	9.35	Green
Winter Wren	11.23	Green
Wood Thrush	8.39	Green

[a] Values represent the minimum effect size detectable under current monitoring conditions.

3.3 SPATIAL ANALYSIS

3.3.1 Species Richness, Diversity and Total Abundance

Monitoring Question: Are there spatial differences in forest bird richness, diversity and total abundance?

- Forest bird species richness was significantly lower in the Lower Watershed relative to the Middle Watershed.
- Watershed-wide, total abundance of all species was significantly higher in 2008 than 2004, 2005 and 2007.

Species richness was significantly lower in the Lower than the Middle Watershed (F=0.960, p=0.039; Table 14, Fig. 9). In the Lower Watershed between 38 and 45 species were detected annually, versus 49 to 56 in the Middle Watershed. Species richness in the Upper Watershed was intermediate with between 47 to 52 species detected annually. There was no effect of Physiographic Zone on species diversity (F=1.319, p=0.287; Table 14, Fig. 10). Although no spatial differences were detected, forest bird relative abundance was significantly higher in 2008 than 2004, 2005, 2006 and 2007 (F=10.249, p<0.0001; Table 13, Fig. 11).

It is well documented that urbanization results in a decline in overall species richness, with only a few urban-tolerant bird species becoming dominant in urban bird communities (Degraaf and Wentworth 1981; Blair 1996; Marzluff 2001; Chace and Walsh 2006). This pattern was also observed in the Credit River Watershed where species richness was significantly higher in the forested Middle Watershed relative to the heavily urbanized Lower Watershed. Interestingly, bird densities are also expected to increase and species diversity is expected to decrease with intensification of urban land-use (Chace and Walsh 2006). However these trends were not observed in the Credit River Watershed. It is unclear why higher abundances of birds were detected in 2007 than 2004, 2005 and 2008, watershed-wide. Further monitoring will allow for the detection of changes in these community parameters over the long-term as urbanization of the Lower Watershed continues.

Table 14. Comparison of community metrics among three Physiographic Zones of the Credit River Watershed between 2002 and 2008.

Community Metric	**Abundance (# individuals/point) Mean (± SE)**			**Time Effect**		**Physiographic Effect** [b]		**Observed Trend**
	Lower	**Middle**	**Upper**	***F***	***P***	***F***	***P***	
Species Richness [a c]	16.38±2.52	22.96±2.05	20.75±1.87	1.156	0.295	**0.960**	**0.039**	Lower < Middle
Species Diversity [a]	2.50±0.17	4.07±0.12	3.76±0.07	0.853	0.552	1.319	0.287	None
Total Abundance	16.79±2.68	16.81±1.27	16.52±0.87	**10.249**	**<0.0001**	0.185	0.832	2004, 2005, 2006, 2007 < 2008

[a] Repeated Measures ANCOVA conducted for species whose relative abundance was significantly related to patch size.
[b] Physiographic differences were determined with Repeated Measures ANOVA.
[c] Species richness was the only community metric for which there was a difference between Physiographic Zones.

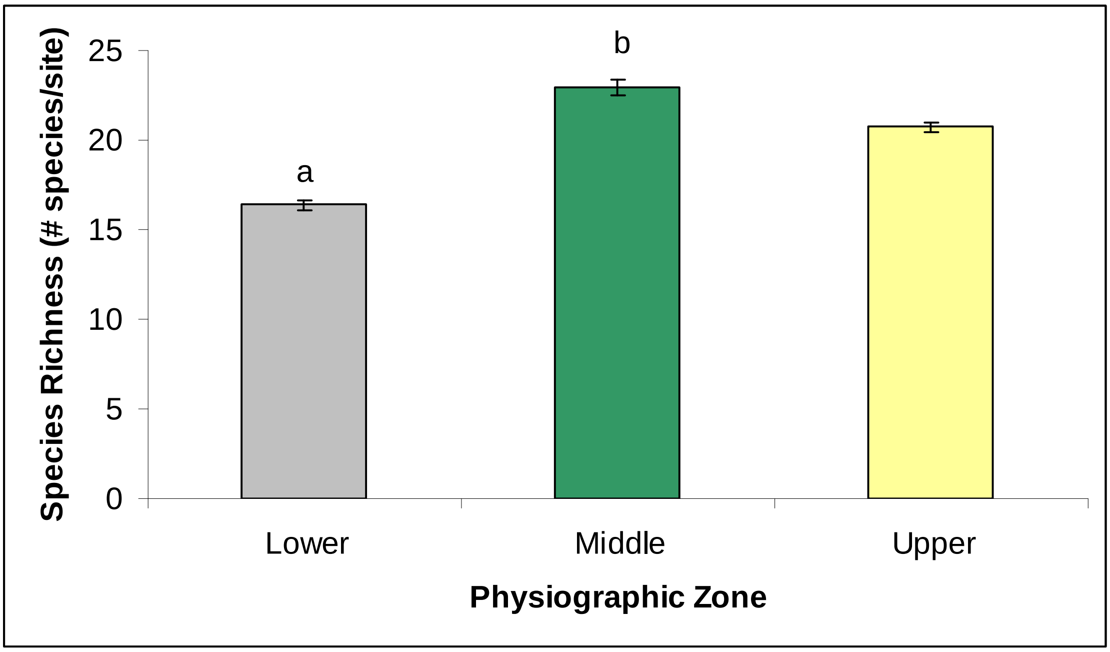


Figure 9. Mean species richness per site in each of the three Physiographic Zones between 2002 and 2008. Bars with different letters indicate a significant difference according to Tukey's HSD test for unequal sample sizes ($p<0.05$). Error bars indicate +/- SE**.**

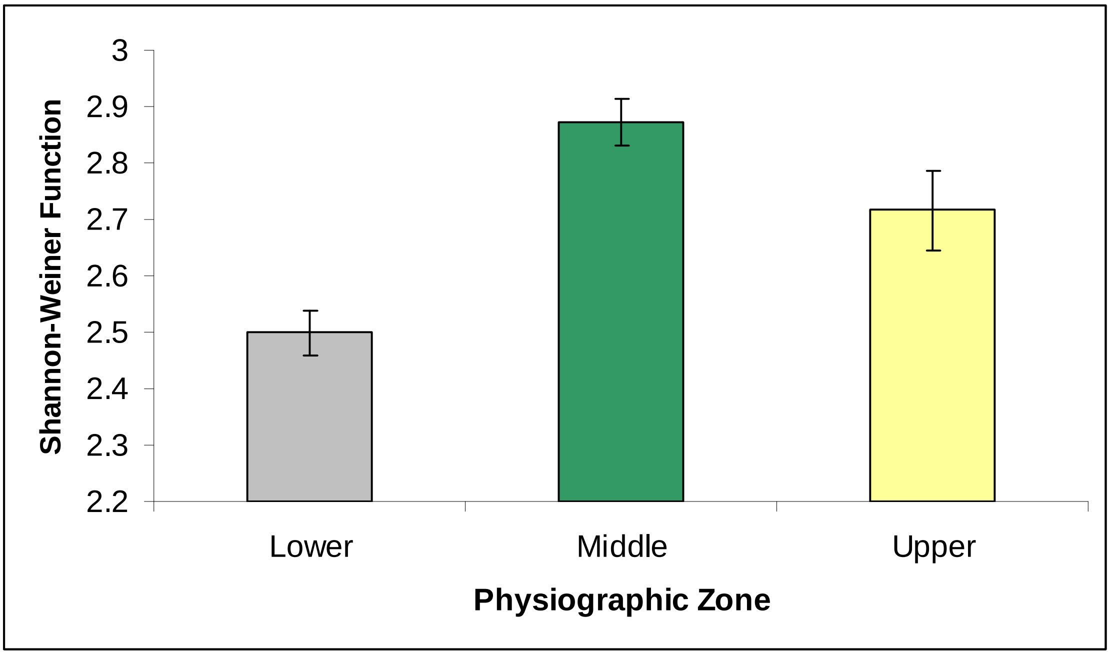


Figure 10. Mean species diversity per site in each of the three Physiographic Zones between 2002 and 2008. Bars with different letters indicate a significant difference according to Tukey's HSD test for unequal sample sizes ($p<0.05$). Error bars indicate +/- SE

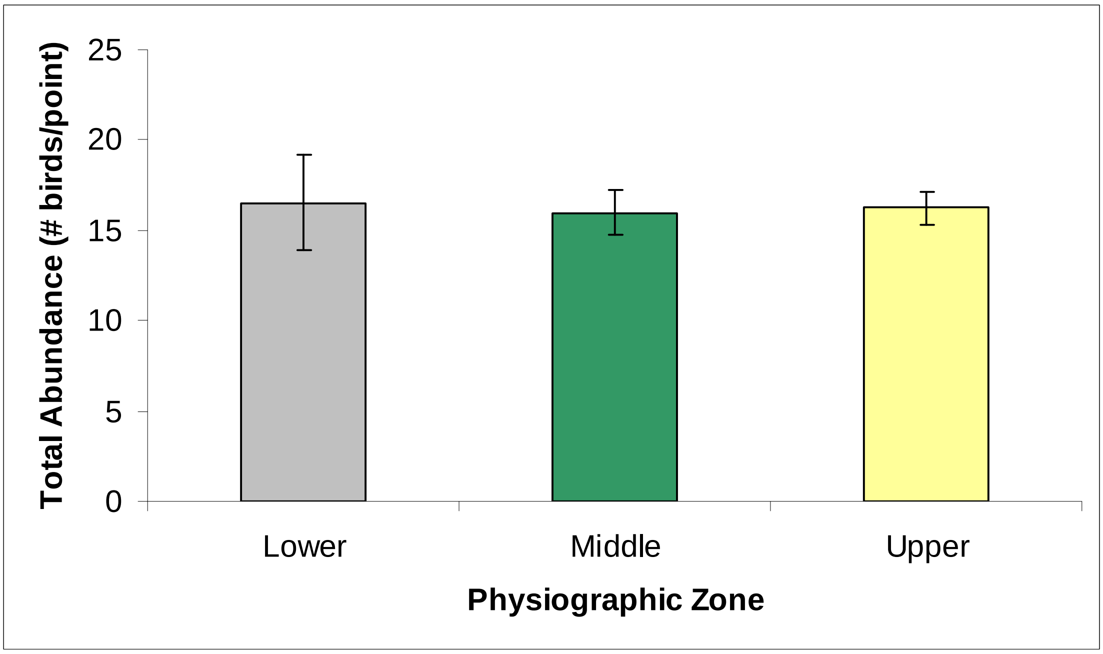


Figure 11. Mean forest bird abundance (# of birds/point) of all species combined in each of the three Physiographic Zones between 2002 and 2008. Bars with different letters indicate a significant difference according to Tukey's HSD test for unequal samp ple sizes (*p*<0.05). Error bars indicate +/- SE.

3.3.2 Forest Bird Guild Relative Abundance

Monitoring Question: Are there spatial differences in forest bird guild relative abundance?

- Relative abundance of birds in eight guilds showed spatial differences among the three Physiographic zones.
- Relative abundances of birds in six guilds were also more abundant in some monitoring years than others.

Short-distance Migrants (F=9.811, p=0.001), Habitat Generalists (F=6.385, p=0.007), Edge/Early Successional Species (F=10.238, p<0.003) and Shrub Nesters (F=15.391, p=<0.0001) were more abundant in the Lower than the Middle and Upper Watersheds (Table 15, Fig. 12, 13 & 14). Long-distance Migrants (F=12.735, p=0.002), Forest Associates (F=19.771, p<0.0001), Canopy/Sub-canopy Nesting Species (F=17.487, p<0.0001) and Ground Nesting Species (F=17.012, p=<0.0001) were more abundant in the Middle and Upper Watersheds than the Lower Watershed (Table 15, Fig. 12, 13 & 14).

Table 15. Comparison of relative abundance of bird guilds among three Physiographic Zones of the Credit River Watershed between 2002 and 2008.

Bird Guild	Abundance (# individuals/point) Mean (± SE)			Time Effect		Physiographic Effect		Observed Trend
	Lower	**Middle**	**Upper**	***F***	***P***	***F***	***P***	
Migratory Guild								
Residents [c]	6.69±0.65	6.71±0.69	6.48±0.69	**16.135**	**<0.0001**	0.0450	0.956	2008 & 2007>2002, 2003, 2004, 2005, 2006
Short-distance Migrants [a]/[b]	8.06±0.78	3.55±0.79	4.06±0.99	**2.606**	**0.021**	**9.811**	**0.001**	Lower > Middle & Upper 2008 & 2005>2002
Long-distance Migrants [a]	3.67±0.53	6.39±0.46	7.26±0.66	**3.912**	**0.001**	**12.735**	**0.0002**	Lower < Middle and Upper 2008>2002 & 2003
General Habitat Association Guilds								
Forest Associates [a]	4.37±0.61	7.82±0.57	9.58±0.57	**10.309**	**<0.0001**	**19.771**	**<0.0001**	Lower < Middle & Upper 2008, 2007, 2006>2002, 2003, 2004
Habitat Generalists [a]	9.92±0.91	6.61±0.96	5.35±0.98	1.985	0.072	**6.385**	**0.007**	Lower > Middle & Upper
Edge/ Early Successional Species [a]	2.12±0.16	1.30±0.18	0.84±0.29	0.902	0.499	**10.238**	**0.003**	Lower > Middle & Upper
Nesting Guild								
Ground Nesters [a]	0.25±0.03	2.09±0.31	2.53±0.31	**2.886**	**0.012**	**17.012**	**<0.0001**	Lower < Middle & Upper 2008>2007
Shrub Nesters [a]	9.31±0.78	4.71±0.76	3.77±0.78	1.657	0.137	**15.391**	**<0.0001**	Lower> Middle & Upper
Canopy/Sub-canopy Nesters [a]	3.719±0.62	5.98±0.66	6.18±0.70	**3.832**	**0.002**	**17.487**	**<0.0001**	Lower< Middle & Upper 2008>2003, 2004, 2005 2007>2004
Cavity Nesting Birds [a]	4.96±0.47	3.94±0.50	3.52±0.50	1.421	0.211	2.418	0.112	None
Foraging Guild								
Aerial Foragers [c]	1.47±0.21	1.64±0.22	1.94±0.22	0.882	0.509	1.153	0.333	None

[a] Repeated Measures ANCOVA conducted for species whose relative abundance was significantly related to patch size.
[b] Friedman Test conducted to test effect of time on relative abundance of species for which data could not be normalized. Kruskal Wallis test conducted for each year separately to test for effect of Physiographic Zone on relative abundance of those same species, with *H* and *p* values shown for 2008 tests only.
[c] Physiographic differences were determined with Repeated Measures ANOVA.

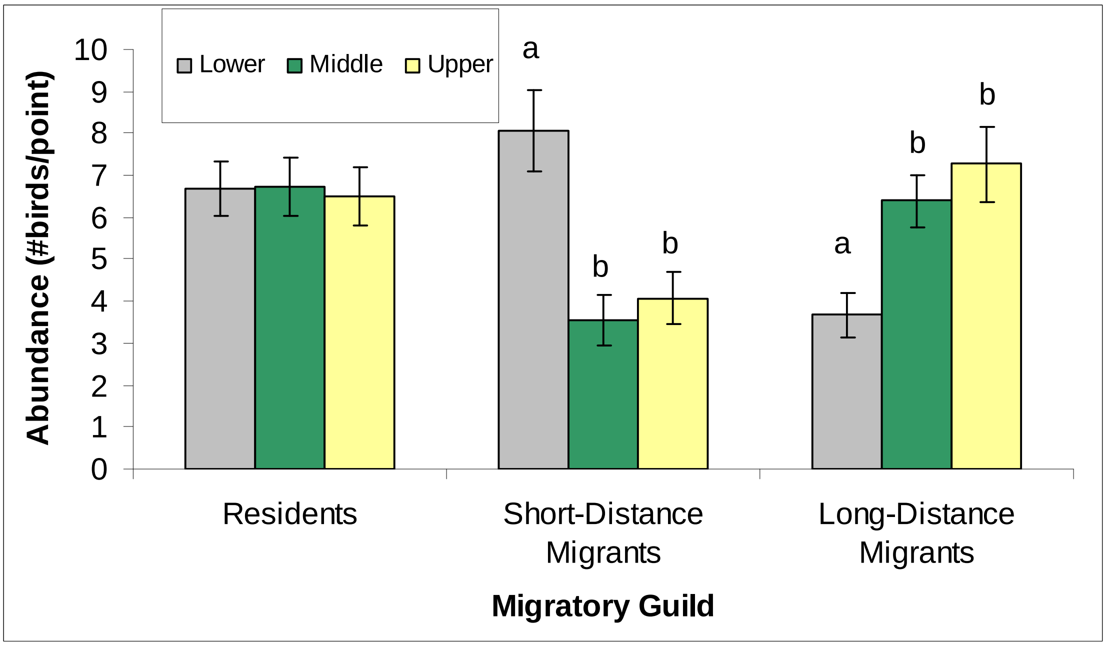


Figure 12. Mean relative abundance of Migratory Guilds (# of birds/point) in each of the three Physiographic Zones between 2002 and 2008. Bars with different letters indicate a significant difference according to Tukey's HSD test for unequal sample sizes (p<0.05). Error bars indicate +/- SE.

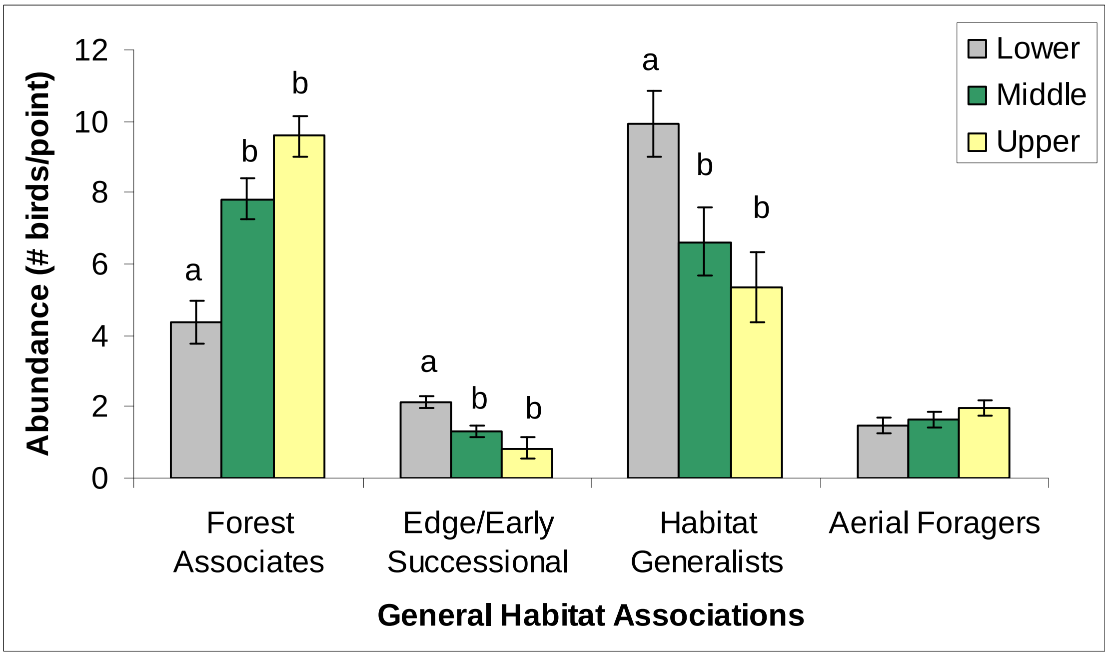


Figure 13. Mean relative abundance of General Habitat Guilds (# of birds/point) in each of the three Physiographic Zones between 2002 and 2008. Bars with different letters indicate a significant difference according to Tukey's HSD test for unequal sample sizes (p<0.05). Error bars indicate +/- SE.

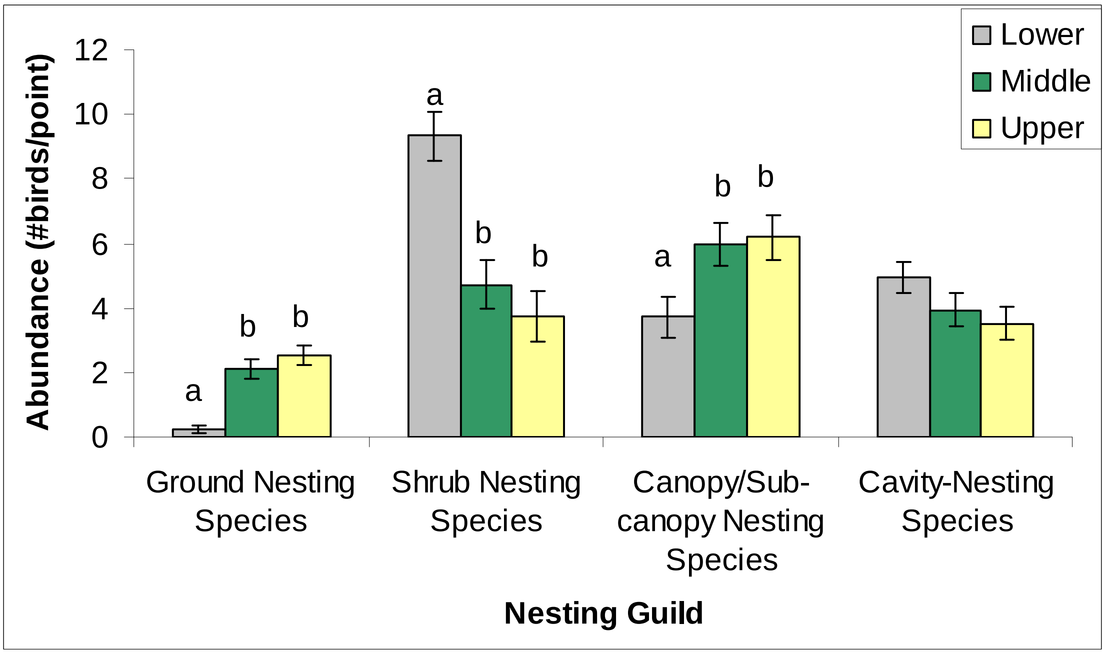


Figure 14. Mean relative abundance of Nesting Guilds (# of birds/point) in each of the three Physiographic Zones between 2002 and 2008. Bars with different letters indicate a significant difference according to Tukey's HSD test for unequal sample sizes ($p<0.05$). Error bars indicate +/- SE.

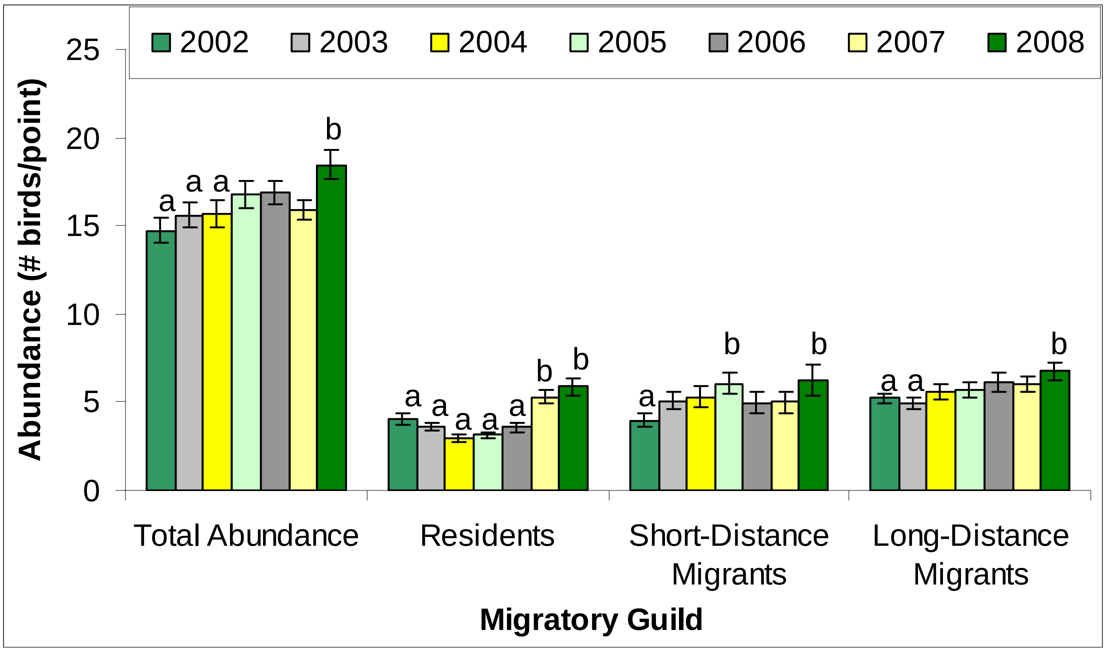


Figure 15. Mean forest bird abundances across sites, as affected by year, for all species, Resident Species, Short-Distance Migrants and Long-distance Migrants (# of birds/point). Bars with different letters indicate a significant difference according to Tukey's HSD test for unequal sample sizes ($p<0.05$). Error bars indicate +/- SE.

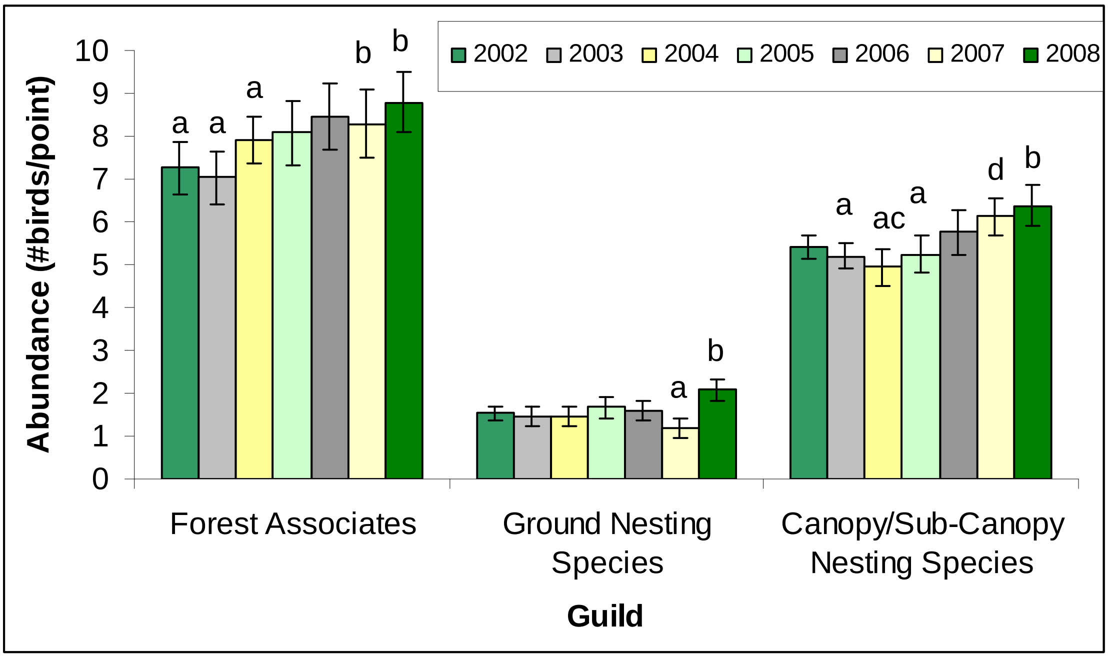


Figure 16. Mean forest bird abundance across sites, as affected by year, for Forest Associates, Ground Nesting Species and Canopy/Sub-Canopy Nesting Species (#birds/point). Bars with different letters indicate a significant difference according to Tukey's HSD test for unequal sample sizes (p<0.05). Error bars indicate +/- SE.

Similar to trends observed in the trend analyses, Residents were more abundant 2007 & 2008 than all previous years (F=16.135, p<0.0001), Short-Distance Migrants were more abundant in 2008 and 2005 than 2002 (F=2.606, p<0.0001), Long-Distance Migrants were more abundant in 2008 than 2002 and 2003 (F=3.919, p=0.001), and Canopy/Sub-canopy Nesting species were more abundant in 2008 than 2003, 2004 and 2005, and in 2007 than 2004 (F=3.832, p=0.002; Table 15, Fig. 15 &16). Two additional guilds, Forest Associates and Ground Nesting Species, were also more abundant in 2008 to 2006 than 2002 to 2004 (F=10.309, p<0.0001), and in 2008 than 2007 (F=2.886, p=0.012), respectively, however, these observations were not reflected in the trend analyses (Table 15, Fig. 15 & 16). Although it is unclear whether this will result in an overall increasing trend over the long-term for these two guilds, with the rapid urbanization of the Lower Watershed, this is unlikely to occur Watershed-wide.

It is well documented that urban areas have higher proportions of edge, early successional and shrub habitats than forested landscapes (Marzluff 2001). By providing an abundance of breeding habitat for species associated with edge and successional habitats, as well as shrub nesting species, the Lower Watershed zone is able to support higher densities of birds belonging to these two guilds than the Middle and Upper Physiographic Zones. Habitat Generalists are also often considered Urban Associates (Appendix B), so it is not surprising that this guild was more abundant in the Lower Watershed. It is unclear however why Short-Distance Migrants were more abundant in the Lower Physiographic Zone. Many species making up the guild are associated with shrubby habitats, which are more abundant in urbanized areas (Marzluff 2001; Cadman et al. 2008). Short-distance Migrants are also not as adversely affected by small woodlot size as Long-distance Migrants and Forest Associates (Blake and Karr 1987; Friesen et al. 1995; Villard et al. 1995). Inhabiting regions that are not desirable to other guilds, may be an effective mechanism for Short-Distance Migrants to reduce competition for food and nesting resources. It is well documented that densities of Habitat Generalists increase in urban areas, and that bird communities in these urbanized environments are dominated by generalist species (Marzluff 2001). This supports the higher densities of Habitat Generalists in observed in the Lower Watershed relative to the Middle and Upper Physiographic Zones.

The higher relative abundance of Long-distance Migrants, Forest Associates and Ground Nesting Species in the Middle and Upper Watershed zones are consistent with North American studies in which species richness and densities of migratory songbirds, Forest Associates and specialized bird species such as Ground Nesting Species were positively correlated with forest patch size and negatively correlated with increasing housing density and forest fragmentation (Friesen et al. 1995; Villard et al. 1995; Donovan et al. 1995; Marzluff 2001; Burke and Nol 2000; Fahrig 2003; Chace and Walsh 2006). Densities of Forest Associates are also positively correlated with proximity to closest forest patch (Villard et al. 1995). Forest patches in the Lower Watershed are smaller, more fragmented, farther apart and have higher housing densities than forests in the Middle and Upper Watersheds.

3.3.3 Individual Species

Monitoring Question: Are there spatial differences relative abundance of individual species?

- Nine species showed spatial differences in relative abundance among three physiographic zones.
-Watershed-side three species were more abundant some years than others.

Five bird species, American Robin (F=5.859, p=0.009), Common Grackle *(Quiscalus quiscula*; F=11.002, p=0.004), Downy Woodpecker (*Picoides pubescens*; F=5.189, p=0.015), Northern Cardinal (F=11.221, p=0.004) and Northern Flicker (F=3.350, p=0.050) were more abundant in the Lower than the Middle and Upper Watersheds. Blue Jay (F=3.541, p=0.046) was also more abundant in the Lower than the Upper Watershed. The remaining three bird species, American Crow (F=16.354, p<0.001), Ovenbird (F=5.240, p=0.014) and Scarlet Tanager *(Piranga olivacea*; F=3.941, p=0.034) were more abundant in the Middle and Upper Watersheds than the Lower Watershed (Table 16).

Watershed-wide American Robin was more abundant in 2006-2008 than 2002 (F=2.762, p=0.015). Black-capped Chickadee relative abundance was also higher in 2006, 2005 and 2008 than 2002 (F=4.079, p<0.001). Red-eyed Vireo was more abundant 2005-2008 than 2002 (F=4.869, p<0.001). These results are consistent with the increasing population trends detected in the trend analyses for the three species (Table 16).

Table 16. Comparison of relative abundance of 18 bird species among three Physiographic Zones of the Credit River Watershed between 2002 and 2008.

Bird Species	**Abundance (# individuals/point) Mean (± SE)**			**Time Effect**		**Physiographic Effect [a]**		**Observed Trend**
	Upper	**Middle**	**Lower**	***F***	***P***	***F***	***P***	
American Crow [b]	1.56±0.17	1.66±0.13	0.52±0.21	**2.310**	**0.037**	**16.354**	**<0.001**	Lower < Middle and Upper
American Robin [b]	0.75±0.11	0.90±0.17	1.76±0.45	**2.762**	**0.015**	**5.859**	**0.009**	Lower > Middle and Upper 2002< 2006, 2007, 2008
Black-capped Chickadee	1.22±0.23	1.29±0.22	1.52±0.41	**4.079**	**<0.001**	**0.626**	**0.545**	2002< 2003, 2005, 2008
Blue Jay [b]	1.06±0.17	0.86±0.11	0.52±0.18	**1.403**	**0.218**	**3.541**	**0.046**	Lower > Upper
Common Grackle [b]	0.15±0.07	0.12±0.04	1.34±0.43	**5.373**	**0.464**	**11.002**	**0.004**	Lower > Middle & Upper
Downy Woodpecker [b]	0.20±0.12	0.21±0.07	0.47±0.12	**1.971**	**0.175**	**5.189**	**0.015**	Lower> Middle & Upper
Eastern Wood-Pewee	0.94±0.14	0.74±0.28	0.61±0.14	0.093	0.763	0.845	0.444	None
Great Crested Flycatcher	0.50±0.12	0.54±0.24	0.47±0.12	0.854	0.531	1.701	0.206	None
Hairy Woodpecker [b]	0.16±0.05	0.19±0.06	0.14±0.09	5.574	0.484	1.189	0.552	None
Northern Cardinal [c]	0.23	0.25±0.09	1.16±0.23	**2.500**	**0.869**	**11.221**	**0.004**	Lower > Middle & Upper
Northern Flicker [b]	0.24±0.10	0.21±0.06	0.42±0.14	**2.311**	**0.442**	**3.350**	**0.050**	Lower > Middle & Upper
Ovenbird [b]	1.32±0.24	0.88±0.21	0.11±0.02	**1.260**	**0.280**	**5.240**	**0.014**	Lower< Middle and Upper
Red-eyed Vireo	1.96±0.25	2.18±0.45	1.47±0.28	**4.869**	**<0.001**	**2.152**	**0.140**	2002 < 2005, 2006, 2007, 2008
Rose-breasted Grosbeak [c]	0.32±0.13	0.25±0.11	0.15±0.11	11.982	0.091	1.644	0.439	None
Scarlet Tanager [b]	0.20±0.02	0.21±0.15	0.02±0.01	**0.672**	**0.422**	**3.941**	**0.034**	Lower< Middle & Upper
White-breasted Nuthatch [b]	0.29±0.11	0.31±0.08	0.22±0.13	1.440	0.205	0.566	0.576	None
Wood Thrush [b]	0.35±0.23	0.33±0.15	0.22±0.12	1.049	0.397	0.732	0.492	None

[a] Physiographic differences were determined with Repeated Measures ANOVA or Repeated-measures ANCOVA.
[b] Repeated Measures ANCOVA conducted for species whose relative abundance was significantly related to patch size.
[c] Friedman Test conducted to test effect of time on relative abundance of species for which data could not be normalized. Kruskal Wallis test conducted for each year separately to test for effect of Physiographic Zone on relative abundance of those same species, with *H* and *p* values shown for 2008 tests only.

Studies have confirmed that all five species that were more abundant in the Lower than the Middle and Upper Watersheds, respond positively to urbanization (Chace and Walsh 2006). For both American Robin and Northern Cardinal these associations were attributed to increased food availability in urban areas (Johnston 2001).

Ovenbird and Scarlet Tanager are both area sensitive, mature habitat associates that are more abundant in regions with high forest cover and in forest patches that are closer together (Villard et al. 1995; Mowbray 1999; Roberts and Norman 1999; Trzcinski et al. 1999; Burke and Nol 2000; Holmes and Sherry 2001). Their habitat requirements are therefore better fulfilled in the more forested, less fragmented forests of the Middle and Upper Watersheds relative to the heavily urbanized Lower Physiographic Zone.

The higher densities of American Crow in the Middle and Upper Watershed zones are likely associated with their reliance on open natural habitats for foraging and larger trees for nesting (Verbeek and Caffrey 2002). It is interesting to note that although common to urban areas, urban crows have lower reproductive success than those inhabiting more natural areas, due to reduced food quality, interspecific interference during breeding, higher densities of nest predators such as squirrels and racoons, and urban specific hazards such as collisions with windows and automobiles (Marzluff et al. 2001). Blue Jay densities are believed to be highest in urban areas with mature trees due to increased food availability (bird feeders) and fewer nest predators that target jays (Tarvin and Woolfenden 1999). It is therefore no surprise that Blue Jay densities were significantly higher in the Lower than the Upper Watershed. Intermediate populations in the Middle Watershed may be attributed to the availability of a high diversity of habitat types that provide essential foraging and nesting substrates for jays that are unable or unwilling to nest in the urbanized Lower Watershed. Further monitoring will provide insight into population trends and densities of the Blue Jay observed in the Middle Watershed.

3.3.4 Power Analysis

Power analysis was completed for all forest bird parameters that were analyzed with Repeated Measures ANOVA. According to power analysis monitoring of 27, 15 and 9 sites annually would be needed to detect 1, 2 and 3 SD of temporal change, respectively, over seven monitoring years for all forest bird parameters. Therefore, a sufficient number of sites were monitored to detect significant temporal changes in forest bird parameters with 90% power at an 80% confidence level for effect sizes greater than or equal to 2 SD. In 2008, the program added two additional monitoring sites. Therefore, in the future, it will be possible to detect significant temporal changes of 1 SD for bird parameters. In order to detect significant spatial trends in forest bird parameters, 9, 5 and 3 sites must be monitored annually in each of the three Physiographic Zones. Again, a sufficient number of sites were monitored to detect significant spatial changes in forest bird parameters with 90% power at an 80% confidence level for effect sizes greater than or equal to 2 SD. In order to detect spatial changes of 1 SD, the program would need to add one additional monitoring plot in each of the Middle and Upper Watershed zones. It is important to note that the program is currently able to detect changes small enough that are established as warning and critical thresholds.

3.4 LANDSCAPE ANALYSIS

Monitoring Question: Was there a correlation between forest bird parameters and landscape metrics in the Credit River Watershed?

- Thirty-two of the forest bird parameters were correlated with at least one of the landscape metrics.
- Most correlations were consistent with trends reported in the literature and were reflective of land-use characterization of the three Physiographic Zones.

Spearman rank correlation was used to examine relationships between forest bird parameters and landscape metrics 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).

Comparisons were made between thirty-two forest bird parameters and five landscape metrics. Only four of the forest bird parameters were not significantly correlated with at least one landscape metric: species abundance, Resident Species abundance, Aerial Forager abundance and Great Crested Flycatcher abundance (Tables 17 & 18). The results of the Spearman rank correlations were consistent with observed trends and proposed explanations comparing breeding bird abundance and community structure among the three Physiographic Zones.

It is well understood that forest bird species richness and densities of forest specialists are higher in larger forest patches (Freemark and Merriam 1986; Blake and Karr 1987). This corroborates findings in the Credit River Watershed where Species Richness, Diversity and abundances of Forest Associates, Ground Nesting and Canopy/Sub-Canopy Nesting Species were positively correlated with habitat patch size Table 17). Seven of the eight individual species that were positively correlated with habitat patch size were classified as Forest Associates that were either Ground or Canopy/Sub-Canopy Nesting Species. Although the remaining species, American Crow, was classified as a Habitat Generalist, it is well documented that crows require large patches of treed areas for breeding purposes (Verbeek and Caffrey 2002; Marzluff et al. 2001). Of the fourteen parameters positively correlated with habitat patch size, nine were also more abundant in the Middle and Upper Physiographic Zones, which on average, have larger habitat patches than in the Lower Watershed.

Generally, parameters that were positively correlated with percent natural cover (i.e. Species Richness, Long Distance Migrants, Forest Associates, Ground Nesting Species and Canopy/Sub-Canopy Nesting Species), were negatively correlated with percent urban cover and *vice versa* (Table 18). This is expected as percent natural cover was negatively correlated with percent urban cover (Spearman R=-0.63, p=0.0007). The landscape matrix has a large influence on forest bird species composition and structure (Askins et al. 1987; Andren 1992; Friesen et al. 1995; Donovan et al. 1995). Urbanization often affects plant species diversity and structural complexity, which influence the availability of breeding sites, foraging microhabitats and composition and abundance of bird and nest predators (Angelstam 1986; James and Warner 1982; Martin 1987; Martin 1988; Andren 1992; Haskell 1995; Saab 1999). Strong evidence exists that species richness, densities of migratory songbirds and forest associates are positively correlated with forest patch size and negatively correlated with increasing housing density and forest fragmentation, while urban areas are usually associated with lower species richness and diversity, with higher abundances of edge/early successional, shrub nesting and generalist bird species (Friesen et al. 1995; Villard et al. 1995; Blair 1996; Donvan et al. 1995; Marzluff 2001; Burke and Nol 2000; Fahrig 2002; Chace and Walsh 2006). Results from the Spearman rank correlation therefore indicate that observed trends in the Credit River Watershed support those documented in the literature. Similar to trends observed with habitat patch size, forest bird parameters that were positively correlated with percent natural cover were more abundant in the Middle and Upper Watersheds than in the Lower Physiographic Zone.

American Crow abundance was positively correlated with percent agriculture cover, which is consistent with research indicating that crows spend a large component of their time feeding in agricultural fields and along rural roads (Marzluff et al. 2001; Verbeek and Caffrey 2002). However, significant correlations between percent agriculture cover and the remaining parameters are more difficult to explain. It is unclear why Blue Jay and Black-capped Chickadee abundances were positively correlated with agriculture, unless the availability of supplemental food sources provided in the form of crops and bird feeders sustain these resident species throughout the challenging winter season. Although it is difficult to explain why Ground Nesting Bird abundance was positively correlated with percent agriculture cover itself, it may have more to do with the shrubby habitats that have become more prevalent in agricultural areas in the recent past. Many forest Ground Nesting Species, such as American Woodcock, Blue-winged Warbler, Eastern Towhee, Hermit Thrush and Mourning Warbler, are known to nest either at the base of shrubs or in shrub thickets found at forest edges or canopy gaps (Ehrlich et al. 1988). As farming intensity declines, especially in the Upper Watershed, early successional and thicket habitats have become more prevalent, and may be inviting to Ground Nesting Species that build nests in shrubby locations.

Matrix Quality is an index, with higher values indicating more natural cover in a given area. It is positively correlated with habitat patch size (Spearman R=0.842, $p<0.0001$) and percent natural cover (Spearman R=0.927, $p<0.0001$), and negatively correlated with percent urban cover (Spearman R=-0.805, $p<0.0001$). Therefore, forest bird parameters that were positively correlated with percent natural cover and habitat patch size (i.e. Species Richness, Long Distance Migrants, Forest Associates, Ground Nesting Species and Canopy/Sub-Canopy Species), were also positively correlated with matrix quality. Parameters that were positively correlated with percent urban cover such as Short-Distance Migrants, Edge/Early Successional Species, Habitat Generalists and Shrub Nesting Species, were also negatively correlated with matrix quality.

Table 17. Spearman rank correlations between forest bird parameters with habitat patch size and matrix quality.

Forest Bird Variable	Habitat Patch Size		Matrix Quality	
	Spearman R	*P* value [a]	Spearman R	*P* value [a]
Community Metrics				
Species Richness	**0.515**	**0.007**	**0.596**	**0.001**
Species Diversity	**0.476**	**0.014**	**0.555**	**0.003**
Species Abundance	0.118	0.567	0.161	0.433
Guilds				
Migratory Guilds				
Resident Species	-0.137	0.504	-0.077	0.709
Short-Distance Migrants	**-0.487**	**0.012**	**-0.556**	**0.004**
Long-Distance Migrants	**0.757**	**<0.0001**	**0.826**	**<0.0001**
Nesting Guilds				
Forest Associates	**0.765**	**<0.0001**	**0.791**	**<0.0001**
Edge/Early Successional Species	-0.612	0.0009	**-0.592**	**0.001**
Habitat Generalists	-0.498	0.009	-0.331	0.098
Nesting Guilds				
Ground Nesting Species	**0.564**	**0.003**	**0.644**	**0.0004**
Shrub Nesting Species	**-0.505**	**0.008**	**-0.441**	**0.024**
Canopy/Sub-canopy Nesting Species	**0.594**	**0.001**	**0.708**	**<0.0001**
Cavity-nesting Species	**-0.427**	**0.030**	**-0.489**	**0.013**
Foraging Guild				
Aerial Foragers	0.364	0.068	0.369	0.069
Individual Species				
American Crow	**0.562**	**0.003**	**0.521**	**0.008**
American Robin	**-0.461**	**0.020**	-0.372	0.067
Black-capped Chickadee	-0.289	0.162	-0.333	0.104
Black-throated Green Warbler	**0.713**	**<0.0001**	**0.779**	**<0.0001**
Blue Jay	**0.501**	**0.011**	**0.424**	**0.034**
Common Grackle	**-0.616**	**0.001**	**-0.700**	**<0.0001**
Downy Woodpecker	**-0.637**	**0.0006**	**-0.759**	**<0.0001**
Eastern Wood-pewee	0.326	0.111	**0.414**	**0.039**
Great Crested Flycatcher	0.106	0.616	0.089	0.674
Hairy Woodpecker	**0.419**	**0.0369**	0.273	0.187
Northern Cardinal	**-0.803**	**<0.0001**	**-0.863**	**<0.0001**
Northern Flicker	**-0.473**	**0.017**	-0.371	0.068
Ovenbird	**0.698**	**0.0001**	**0.699**	**0.0001**
Red-eyed Vireo	0.383	0.059	0.357	0.080
Rose-breasted Grosbeak	0.368	0.070	**0.444**	**0.027**
Scarlet Tanager	**0.817**	**<0.0001**	**0.642**	**0.0005**
White-breasted Nuthatch	**0.210**	**0.313**	0.284	0.168
Wood Thrush	**0.396**	**0.049**	0.330	0.107

[a] Results considered significant when $p<0.05$ and are reported in bold.

Table 18. Spearman rank correlations between forest bird parameters with % Agriculture, Natural and Urban cover.

Forest Bird Variable	% Agriculture		% Natural		% Urban	
	Spearman R	*P* value [a]	Spearman R	*P* value [a]	Spearman R	*P* value [a]
Community Metrics						
Species Richness	0.149	0.467	**0.573**	**0.002**	-0.264	0.192
Species Diversity	0.333	0.096	0.487	0.230	-0.365	0.664
Species Abundance	0.145	0.481	0.169	0.408	0.135	0.511
Guilds						
Migratory Guilds						
Resident Species	0.437	0.025	-0.022	0.914	0.135	0.511
Short-Distance Migrants	0.009	0.964	**-0.605**	**0.001**	**0.456**	**0.019**
Long-Distance Migrants	0.253	0.212	**0.853**	**<0.0001**	**-0.681**	**0.0002**
Nesting Guilds						
Forest Associates	0.259	0.202	**0.818**	**<0.0001**	-0.646	0.077
Edge/Early Successional Species	-0.143	0.486	**-0.504**	**0.009**	**0.663**	**0.0005**
Habitat Generalists	0.136	0.506	**-0.553**	**0.004**	**0.401**	**0.042**
Nesting Guilds						
Ground Nesting Species	**0.473**	**0.015**	**0.545**	**0.004**	**-0.459**	**0.018**
Shrub Nesting Species	-0.161	0.434	**-0.428**	**0.029**	**0.616**	**0.0008**
Canopy/Sub-canopy Nesting Species	0.241	0.235	**0.792**	**<0.0001**	**-0.438**	**0.028**
Cavity-nesting Species	0.246	0.266	**-0.557**	**0.004**	0.345	0.085
Foraging Guild						
Aerial Foragers	0.172	0.400	0.338	0.099	-0.076	0.711
Individual Species						
American Crow	**0.441**	**0.027**	**0.578**	**0.002**	**-0.601**	**0.002**
American Robin	-0.239	0.251	**-0.409**	**0.042**	**0.421**	**0.036**
Black-capped Chickadee	**0.513**	**0.009**	-0.379	0.062	0.055	0.794
Black-throated Green Warbler	0.268	0.195	**0.811**	**<0.0001**	**-0.634**	**0.0007**
Blue Jay	**0.524**	**0.007**	**0.504**	**0.011**	**-0.405**	**0.045**
Common Grackle	-0.235	0.258	**-0.661**	**0.0003**	**0.633**	**0.0007**
Downy Woodpecker	-0.390	0.054	**-0.724**	**<0.0001**	**0.720**	**<0.0001**
Eastern Wood-pewee	0.024	0.911	**0.425**	**0.034**	-0.111	0.597
Great Crested Flycatcher	0.362	0.076	0.077	0.715	-0.249	0.229
Hairy Woodpecker	-0.059	0.780	0.273	0.187	-0.120	0.567
Northern Cardinal	-0.308	0.133	**-0.792**	**<0.0001**	**0.711**	**<0.0001**
Northern Flicker	-0.196	0.347	-0.379	0.061	**0.497**	**0.011**
Ovenbird	0.216	0.299	**0.699**	**0.0001**	**-0.572**	**0.003**
Red-eyed Vireo	-0.151	0.471	**0.492**	**0.012**	-0.057	0.786
Rose-breasted Grosbeak	0.328	0.109	**0.389**	**0.054**	**-0.397**	**0.049**
Scarlet Tanager	-0.085	0.685	**0.753**	**<0.0001**	-0.259	0.210
White-breasted Nuthatch	0.203	0.329	0.237	0.253	-0.179	0.392
Wood Thrush	0.001	0.996	0.371	0.067	-0.103	0.625

[a] Results considered significant when $p<0.05$ and are reported in bold.

It is important to make the connection between landscape metrics, forest bird parameters and trends observed among the three Physiographic Zones. In most cases, forest bird parameters that were positively correlated with habitat patch size, percent natural cover and matrix quality were also more abundant in the Middle and Upper Watersheds than in the Lower Physiographic Zone. Forest bird parameters that were positively correlated with percent urban cover were generally more abundant in the Lower Watershed than the Middle and Upper zones. These findings are consistent with the programs landscape analysis (Credit Valley Conservation 2007) which describes the Lower Watershed as dominated by urban development, while the Middle and Upper zones are characterized by natural cover and agricultural land-use, respectively.

3.5 COMMUNITY COMPOSITION AND STRUCTURE

Monitoring Question: Do forests in the three physiographic zones have unique species assemblages?

- Community Composition can be used to distinguish Lower Watershed forests from Middle and Upper Watershed forests. However, community composition in the Middle Watershed is similar to the Upper Watershed.
- 25 bird species can be used to distinguish among forests of the three physiographic zones in the Credit River Watershed.

Forest bird communities in Lower Watershed forests differed from those observed in forests in the Middle and Upper Watersheds (Table 19). These results are due both to differences in species composition and relative abundance of bird species present.

Forests in the Lower Watershed were characterized by a higher abundance of ten generalist bird species, many of which are urban associates, including American Robin, Baltimore Oriole *(Haliaeetus leucocephalus*), Common Grackle, Downy Woodpecker, European Starling, Gray Catbird *(Dumetella carolinensis)*, House Finch, House Wren, Northern Cardinal and Song Sparrow *(Melospiza melodia;* Table 20). Forests of the Middle Watershed were characterized by eight bird species, including Black-and-white Warbler *(Mniotilta varia)*, Black-throated Green Warbler, Brown Creeper *(Certhia americana)*, Eastern Wood-pewee, Ovenbird, Red-eyed Vireo, White-throated Sparrow *(Zonotrichia albicollis)* and Winter Wren *(Troglodytes troglodytes)*. Most of these species (with the exception of Eastern Wood-pewee, Red-eyed Vireo and White-throated Sparrow), are forest specialists that have a tendency to nest in the interior of large, mature forest patches (Freemark 1989). Upper Watershed forests were characterized by seven species, Chestnut-sided Warbler *(Dendroica pensylvanica)*, Chipping Sparrow, Mourning Warbler *(Oporornis philadelphia)*, Pine Warbler *(Dendroica pinus)*, Swamp Sparrow *(Melospiza georgiana)* Hermit Thrush *(Catharus guttatus)* and Veery. Interestingly, apart from the Pine Warbler, these species all nest in shrubs or at the base of shrubs, often in edge, early successional habitats or canopy gaps in larger forest patches (Ehrlich et al. 1988; Jones and Donovan 1996). Farmland in the Upper Watershed has been farmed less intensively in the recent past which has allowed the land to naturally revert to more meadow and early successional/shrubby habitats. This likely explains the representation of the Upper Watershed by shrub-nesting, edge/early-successional and forest gap associated species.

Table 19. Differences in community composition among the three Physiographic Zones in the Credit River Watershed based on Multi-Response Permutation Procedure.

Year	Average within-group Distance			*T* value	*p*	Significance [a]
	Upper	Middle	Lower			
2002	3.78	3.69	3.55	-4.62	<0.0001	Lower differs from Middle and Upper
2003	4.01	3.88	5.33	-6.29	<0.0001	Lower differs from Middle and Upper
2004	4.45	4.76	5.38	-3.36	0.0005	Lower differs from Middle and Upper
2005	4.29	4.21	6.53	-6.56	<0.0001	Lower differs from Middle and Upper
2006	4.2	4.33	5.27	-4.43	0.0007	Lower differs from Middle and Upper
2007	4.45	4.08	5.06	-6.36	<0.0001	Lower differs from Middle and Upper
2008	4.21	4.19	8.58	-4.77	0.0002	Lower differs from Middle and Upper

[a] For all years, community composition was significantly different in the Lower Watershed Forests than forests in the Middle and Upper Watershed. Community composition in the Middle Watershed could not be distinguished from communities in the Upper Watershed.

Table 20. Forest bird species that can be used to differentiate among the three Physiographic Zones in the Credit River Watershed based on Indicator Species Analysis.

Species	Indicator Value			*p*	Indicator Zone
	Upper	Middle	Lower		
American Robin	25	21	53	0.001	LOWER
Baltimore Oriole	22	6	76	0.001	LOWER
Black-and-white Warbler	3	77	0	0.001	MIDDLE
Black-throated Green Warbler	30	70	0	0.001	MIDDLE
Brown Creeper	33	67	0	0.001	MIDDLE
Chestnut-sided Warbler	76	0	24	0.018	UPPER
Chipping Sparrow	51	28	20	0.017	UPPER
Common Grackle	7	8	85	0.001	LOWER
Downy Woodpecker	23	23	53	0.001	LOWER
Eastern Wood-pewee	30	41	29	0.020	MIDDLE
European Starling	4	0	96	0.001	LOWER
Gray Catbird	0	0	100	0.001	LOWER
Hermit Thrush	100	0	0	0.001	MIDDLE
House Finch	6	11	83	0.031	LOWER
House Wren	25	7	68	0.001	LOWER
Mourning Warbler	75	13	12	0.002	UPPER
Northern Cardinal	15	14	71	0.001	LOWER
Ovenbird	39	58	3	0.002	MIDDLE
Pine Warbler	58	26	16	0.001	UPPER
Red-eyed Vireo	35	40	25	0.001	MIDDLE
Song Sparrow	34	12	55	0.001	LOWER
Swamp Sparrow	68	23	9	0.020	UPPER
Veery	68	28	5	0.001	UPPER
White-throated Sparrow	13	87	0	0.001	MIDDLE
Winter Wren	29	71	0	0.001	MIDDLE

4.0 CONCLUSIONS

Overall, forest bird community parameters in the Credit Rive Watershed were stable between 2002 and 2008 with no significant changes in Species Diversity and Community Turnover. Relative Abundance and Species Richness did exhibit increasing trends over the monitoring period, some of which is influenced by a larger number of Species at Risk detected in 2008 than any other years. Milder winters, increasing forest cover in regions across Ontario and increased popularity of bird feeders also likely influence the observed trends. Further monitoring will allow us to determine whether this is a long-term trend, and potentially elucidate the driving mechanisms behind the observed increase.

There were some notable Watershed-wide population trends detected for a number of guilds and individual species. Similar to other bird monitoring programs, Resident and Short-Distance Migratory Species in the Credit River Watershed increased. In addition, Long-Distance Migrants, Habitat Generalists, and Canopy/Sub-canopy Nesting Species showed increasing trends, while Shrub Nesting and Cavity Nesting Species showed a trend towards increasing populations, Watershed-wide. Ground Nesting Species exhibited significant population declines only in the Middle and Upper Watershed zones.

Increasing populations of American Robin, Black-capped Chickadee and Brown-headed Cowbird must be watched closely. These three species are urban associates that respond well to anthropogenic disturbance. Although there is no evidence yet that these species are replacing the more specialist, urban sensitive species Watershed-wide, their increasing representation may indicate that the frequency of disturbed habitat conditions have increased throughout the seven year monitoring period.

Declining populations of the Ovenbird and Northern Flicker in the Credit Watershed reflect trends observed continent and province wide. Although both species are still widespread and relatively common throughout the watershed, intervention may be required to maintain ‘healthy’ populations of these two species over the long-term.

There were many spatial differences in species richness, guild abundance and individual species abundance that generally reflected land-use patterns in the three Physiographic Zones. Overall species composition and abundance were similar between the Middle and Upper Physiographic Zones, likely due to similar forest cover values in the two regions. Most of the detected differences were the Lower compared to the Middle and Upper Watershed regions. These differences may become more extreme as urbanization continues to intensify in the Lower Watershed, while the Niagara Escarpment and Oak Ridges Moraine leave the Middle Watershed in a relatively unchanged condition over the long-term.

Twenty-eight of the thirty-two forest bird parameters were correlated with at least one of the landscape metrics. Guilds and individual species that were considered forest associates or required specialized forest habitat features were positively correlated with percent natural cover, habitat patch size and matrix quality. Guilds and species such as Habitat Generalists and those associated with early successional and thicket habitats showed opposite trends and were positively correlated with percent urban cover and negatively correlated with habitat patch size and matrix quality. Interestingly, guilds and individual species positively correlated with habitat patch size, percent natural cover and matrix quality were also more likely to have higher densities in the Middle and Upper Watersheds than the Lower Physiographic Zone.

Overall, many forest bird community parameters changed between 2002 and 2008. Most of the changes were in the Lower Watershed, which have the potential to become more severe with increasing urbanization. These changes also have the potential to influence the other two Physiographic Zones as land-use pressures do not affect only the immediate zone of disturbance, especially for highly mobile organisms such as birds.

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APPENDIX A: FOREST MONITORING SITES

Table 1. Forest health monitoring sites established throughout the Credit River Watershed.

Site Name	Site #	Township	County	Physiographic Zone	Number of Point Count Stations	Forest Size (Ha)
Britannia Woods	F-16	Mississauga	Peel	Lower	1	5.19
Churchill Meadows Property	F-13	Mississauga	Peel	Lower	1	5.89
Huttonville Property	F-10	Brampton	Peel	Lower	2	18.36
Levi Creek Property	F-11	Mississauga	Peel	Lower	1	24.2
Meadowvale Station	I-05	Mississauga	Peel	Lower	4	45.70
Mississauga Gardens	I-01	Mississauga	Peel	Lower	5	52.36
Roy Ivors Woods	F-14	Mississauga	Peel	Lower	3	24.73
Streetsville Woods Property	F-12	Mississauga	Peel	Lower	3	18.76
Winston Woods	F-15	Oakville	Halton	Lower	1	27.24
Fairy Lake Property	F-18	Halton Hills	Halton Hills	Middle	2	169.10
FON Willoughby Nature Reserve	F-20	Caledon	Peel	Middle	4	93.25
Limehouse Property	F-08	Halton Hills	Halton Hills	Middle	4	135.32
Robert Baker Forest	F-05	Caledon	Peel	Middle	4	232.56
Silver Creek Property	F-07	Halton Hills	Halton Hills	Middle	5	370.14
Terra Cotta Forest	I-06	Caledon	Peel	Middle	5	753.26
Upper Canada Property	F-09	Halton Hills	Halton Hills	Middle	5	141.32
Warwick Property	F-06	Caledon	Peel	Middle	2	191.18
Alton Forest	I-03	Caledon	Peel	Upper	5	185.75
Belfountain Property	F-19	Caledon	Peel	Upper	5	439.15
Caledon Creek Forest (TRCA)	F-04	Caledon	Peel	Upper	3	134.21
Charles Sauriol Property	F-03	Caledon	Peel	Upper	1	233.83
Forks of the Credit	I-04	Caledon	Peel	Upper	5	534.18
Hillsburgh Property	F-02	Erin	Wellington	Upper	2	60.43
Monora Park Property	F-01	Mono	Dufferin	Upper	2	112.06
Orpen Lake	I-02	Caledon	Peel	Upper	5	323.18

APPENDIX B: BIRD SPECIES HABITAT ASSOCIATIONS

Table 1. Ontario Breeding Bird Atlas (OBBA) habitat associations for bird species detected in forest plots of the Credit River Watershed, 2002-2008.

Common Name	Latin Name
Forest Habitats	
American Redstart	*Setophaga ruticilla*
American Woodcock	*Scolopax minor*
Baltimore Oriole	*Icterus galbula*
Black-and-white Warbler	*Mniotilta varia*
Blackburnian Warbler	*Dendroica fusca*
Black-throated Blue Warbler	*Dendroica caerulescens*
Black-throated Green Warbler	*Dendroica virens*
Blue-gray Gnatcatcher	*Polioptila caerulea*
Blue-headed Vireo	*Vireo solitarius*
Broad-winged Hawk	*Buteo platypterus*
Brown Creeper	*Certhia americana*
Canada Warbler	*Wilsonia candensis*
Chipping Sparrow	*Spizella passerina*
Cooper's Hawk	*Accipiter cooperii*
Downy Woodpecker	*Picoides pubescens*
Eastern Wood-pewee	*Contopus virens*
Golden-crowned Kinglet	*Regulus satrapa*
Great Crested Flycatcher	*Myiarchus crinitus*
Great Horned Owl	*Bubo virginianus*
Hairy Woodpecker	*Picoides villosus*
Hermit Thrush	*Catharus guttatus*
Hooded Warbler	*Wilsonia citrina*
Least Flycatcher	*Empidonax minimus*
Louisiana Waterthrush	*Seiurus motacilla*
Magnolia Warbler	*Dendroica magnolia*
Mourning Warbler	*Oporornis philadelphia*
Nashville Warbler	*Vermivora ruficapilla*
Northern Goshawk	*Accipiter gentilis*
Northern Flicker	*Colaptes auratus*
Northern Waterthrush	*Seiurus noveboracensis*
Ovenbird	*Seiurus aurocapilla*
Pileated Woodpecker	*Dryocopus pileatus*
Pine Siskin	*Carduelis pinus*
Pine Warbler	*Dendroica pinus*
Purple Finch	*Carpodacus purpureus*
Red-bellied Woodpecker	*Melanerpes carolinus*
Red-breasted Nuthatch	*Sitta canadensis*
Red-eyed Vireo	*Vireo olivaceus*
Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Ruby-throated Hummingbird	*Archilochus colubris*
Ruffed Grouse	*Bonasa umbellus*
Scarlet Tanager	*Piranga olivacea*
Sharp-shinnned Hawk	*Accipiter striatus*

APPENDIX B: BIRD SPECIES HABITAT ASSOCIATIONS (Cont'd)

Common Name	Latin Name
Forest Habitats (Continued)	
Turkey Vulture	*Cathartes aura*
Veery	*Catharus fuscescens*
Warbling Vireo	*Vireo gilvus*
White-breasted Nuthatch	*Sitta carolinensis*
Wild Turkey	*Meleagris gallopavo*
Winter Wren	*Troglodytes troglodytes*
Wood Thrush	*Hylocichla mustelina*
Yellow-bellied Sapsucker	*Sphyrapicus varius*
Yellow-rumped Warbler	*Dendroica coronata*
Yellow-throated Vireo	*Vireo flavifrons*
Shrub and Early Successional Habitats	
American Goldfinch	*Carduelis tristis*
Black-billed Cuckoo	*Coccyzus erythropthalmus*
Blue-winged Warbler	*Vermivora pinus*
Brown Thrasher	*Toxostoma rufum*
Cedar Waxwing	*Bombycilla cedrorum*
Chestnut-sided Warbler	*Dendroica pensylvanica*
Common Yellowthroat	*Geothlypis trichas*
Eastern Towhee	*Pipilo erythrophthalmus*
Field Sparrow	*Spizella pusilla*
Gray Catbird	*Dumetella carolinensis*
House Wren	*Troglodytes aedon*
Indigo Bunting	*Passerina cyanea*
Northern Cardinal	*Cardinalis cardinalis*
Song Sparrow	*Melospiza melodia*
White-throated Sparrow	*Zonotrichia albicollis*
Yellow Warbler	*Dendroica petechia*
Yellow-billed Cuckoo	*Coccyzus americanus*
Wetland Habitats	
Alder Flycatcher	*Empidonax alnorum*
American Coot	*Fulica americana*
Belted Kingfisher	*Ceryle alcyon*
Canada Goose	*Branta canadensis*
Common Loon	*Gavia immer*
Common Yellowthroat	*Geothlypis trichas*
Double-crested Cormorant	*Phalacrocorax auritus*
Great Egret	*Ardea alba*
Green Heron	*Butorides virescens*
Mallard	*Anas platyrhynchos*
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*
Ring-billed Gull	*Larus delawarensis*
Spotted Sandpiper	*Actitis macularia*
Swamp Sparrow	*Melospiza georgiana*
Wood Duck	*Aix sponsa*

APPENDIX B: BIRD SPECIES HABITAT ASSOCIATIONS (Cont'd)

Common Name	Latin Name
Open Field and Agricultural Habitats	
American Kestrel	*Falco sparverius*
Barn Swallow	*Hirundo rustica*
Bobolink	*Dolichonyx oryzivorus*
Brown-headed Cowbird	*Molothrus ater*
Common Grackle	*Quiscalus quiscula*
Eastern Kingbird	*Tyrannus tyrannus*
Eastern Meadowlark	*Sturnella magna*
Eastern Phoebe	*Sayornis phoebe*
Horned Lark	*Eremophila alpestris*
Killdeer	*Charadrius vociferus*
Red-tailed Hawk	*Buteo jamaicensis*
Red-winged Blackbird	*Agelaius phoeniceus*
Ring-necked Pheasant	*Phasianus colchicus*
Tree Swallow	*Tachycineta bicolor*
Savannah Sparrow	*Passerculus sandwichensis*
Urban Habitats	
American Crow [a]	*Corvus brachyrhynchos*
American Robin [a]	*Turdus migratorius*
Black-capped Chickadee [a]	*Poecile atricapillus*
Blue Jay [a]	*Cyanocitta cristata*
Chimney Swift	*Chaetura pelagica*
House Finch	*Carpodacus mexicanus*
House Sparrow	*Passer domesticus*
European Starling	*Sturnus vulgaris*
Mourning Dove [a]	*Zenaida macroura*
Rock Pigeon	*Columba livia*

[a] Bird species classified as urban habitat associates by OBBA, but have been reclassified by CVC to better represent habitat associations in Credit River Watershed

APPENDIX C: BREEDING BIRD GUILDS

Table 1. General habitat association guilds for breeding birds detected at forest plots in Credit River Watershed, 2002-2008.

General Habitat Associations		
Forest Associate Species	**Edge/Early Successional Species**	**Generalist Species**
Black-and-white Warbler	American Redstart	American Crow
Blackburnian Warbler	American Woodcock	American Goldfinch
Black-throated Blue Warbler	Black-billed Cuckoo	American Kestrel
Black-throated Green Warbler	Blue-winged Warbler	American Robin
Blue-headed Vireo	Brown Thrasher	Baltimore Oriole
Blue-gray Gnatcatcher	Chestnut-sided Warbler	Barn Swallow
Blue Jay	Eastern Towhee	Black-capped Chickadee
Broad-winged Hawk	Gray Catbird	Brown-headed Cowbird
Brown Creeper	Indigo Bunting	Cedar Waxwing
Canada Warbler	Mourning Warbler	Chimney Swift
Cooper's Hawk	Nashville Warbler	Chipping Sparrow
Downy Woodpecker	Northern Cardinal	Common Grackle
Eastern Wood-pewee	Northern Mockingbird	Eastern Phoebe
Golden-crowned Kinglet	Red-tailed Hawk	European Starling
Great Crested Flycatcher	Ruby-throated Hummingbird	Great-horned Owl
Hairy Woodpecker	White-throated Sparrow	House Wren
Hermit Thrush	Yellow-billed Cuckoo	Mourning Dove
Hooded Warbler		Northern Flicker
Least Flycatcher		Red-winged Blackbird
Louisiana Waterthrush		Ring-necked Pheasant
Magnolia Warbler		Song Sparrow
Northern Goshawk		Tree Swallow
Northern Waterthrush		Turkey Vulture
Ovenbird		Yellow Warbler
Pileated Woodpecker		
Pine Siskin		
Pine Warbler		
Purple Finch		
Red-bellied Woodpecker		
Red-breasted Nuthatch		
Red-eyed Vireo		
Rose-breasted Grosbeak		
Ruffed Grouse		
Scarlet Tanager		
Sharp-shinned Hawk		
Veery		
Warbling Vireo		
White-breasted Nuthatch		
Wild Turkey		
Winter Wren		
Wood Duck		
Wood Thrush		
Yellow-bellied Sapsucker		
Yellow-rumped Warbler		
Yellow-throated Vireo		

APPENDIX C: BREEDING BIRD GUILDS (Cont'd)

Table 2. Nest site preference and foraging specialization guilds for breeding birds detected at forest plots in the Credit River Watershed, 2002-2008.

Nest Level Preferences				Foraging Specialization
Ground Nester	**Mid-level Nester**	**Canopy/Sub-canopy Nester**	**Cavity Nester**	**Aerial Insectivores**
American Woodcock	American Robin	American Crow	American Kestrel	Barn Swallow
Black-and-white Warbler	American Goldfinch	Baltimore Oriole	Black-capped Chickadee	Chimney Swift
Blue-winged Warbler	American Redstart	Blackburnian Warbler	Chimney Swift	Eastern Phoebe
Canada Warbler	Black-billed Cuckoo	Black-throated Green Warbler	Downy Woodpecker	Eastern Wood-pewee
Eastern Towhee	Black-throated Blue Warbler	Blue-headed Vireo	European Starling	Great Crested Flycatcher
Hermit Thrush	Brown Creeper	Blue Jay	Great Crested Flycatcher	Least Flycatcher
Louisiana Waterthrush	Brown Thrasher	Blue-gray Gnatcatcher	Hairy Woodpecker	Tree Swallow
Mourning Warbler	Cedar Waxwing	Broad-winged Hawk	House Wren	
Nashville Warbler	Chestnut-sided Warbler	Cooper's Hawk	Northern Flicker	
Northern Waterthrush	Chipping Sparrow	Eastern Wood-pewee	Pileated Woodpecker	
Ovenbird	Common Grackle	Golden-crowned Kinglet	Red-bellied Woodpecker	
Ring-necked Pheasant	Eastern Phoebe	Great Horned Owl	Red-breasted Nuthatch	
Ruffed Grouse	Gray Catbird	Least Flycatcher	Tree Swallow	
Song Sparrow	Hooded Warbler	Northern Goshawk	White-breasted Nuthatch	
Veery	Indigo Bunting	Pine Siskin	Wood Duck	
White-throated Sparrow	Magnolia Warbler	Pine Warbler	Yellow-bellied Sapsucker	
Wild Turkey	Mourning Dove	Purple Finch		
Winter Wren	Northern Cardinal	Red-eyed Vireo		
	Northern Mockingbird	Red-tailed Hawk		
	Red-winged Blackbird	Ruby-throated Hummingbird		
	Rose-breasted Grosbeak	Scarlet Tanager		
	Winter Wren	Sharp-shinned Hawk		
	Wood Thrush	Turkey Vulture		
	Yellow Warbler	Warbling Vireo		
	Yellow-billed Cuckoo	Yellow-rumped Warbler		
		Yellow-throated Vireo		

APPENDIX C: BREEDING BIRD GUILDS (Cont'd)

Table 3. Migratory guilds of bird species detected at forest plots in the Credit River Watershed, 2002-2008.

Migratory Guild		
Resident	**Short-distance Migrant**	**Long-distance Migrant**
American Crow	American Goldfinch	American Redstart
Black-capped Chickadee	American Kestrel	Baltimore Oriole
Blue Jay	American Robin	Barn Swallow
Downy Woodpecker	American Woodcock	Black-and-white Warbler
European Starling	Blue-headed Vireo	Black-billed Cuckoo
Great-horned Owl	Brown Thrasher	Blackburnian Warbler
Hairy Woodpecker	Brown Creeper	Black-throated Blue Warbler
Northern Cardinal	Brown-headed Cowbird	Black-throated Green Warbler
Pileated Woodpecker	Cedar Waxwing	Blue-gray Gnatcatcher
Purple Finch	Chipping Sparrow	Blue-winged Warbler
Red-breasted Nuthatch	Common Grackle	Broad-winged Hawk
Ring-necked Pheasant	Cooper's Hawk	Canada Warbler
Ruffed Grouse	Eastern Towhee	Chestnut-sided Warbler
White-breasted Nuthatch	Eastern Phoebe	Chimney Swift
Wild Turkey	Golden-crowned Kinglet	Eastern Wood-pewee
	Gray Catbird	Great Crested Flycatcher
	Hermit Thrush	Hooded Warbler
	House Wren	Indigo Bunting
	Mourning Dove	Least Flycatcher
	Northern Flicker	Louisiana Waterthrush
	Northern Mockingbird	Magnolia Warbler
	Pine Siskin	Mourning Warbler
	Pine Warbler	Nashville Warbler
	Red-bellied Woodpecker	Northern Goshawk
	Red-tailed Hawk	Northern Waterthrush
	Red-winged Blackbird	Ovenbird
	Song Sparrow	Red-eyed Vireo
	Turkey Vulture	Rose-breasted Grosbeak
	Winter Wren	Ruby-throated Hummingbird
	White-throated Sparrow	Scarlet Tanager
	Wood Duck	Sharp-shinned Hawk
	Yellow-bellied Sapsucker	Tree Swallow
	Yellow-rumped Warbler	Veery
		Warbling Vireo
		Wood Thrush
		Yellow-billed Cuckoo
		Yellow-throated Vireo
		Yellow Warbler

APPENDIX D: BIRD GUILD TOTAL ABUNDANCE

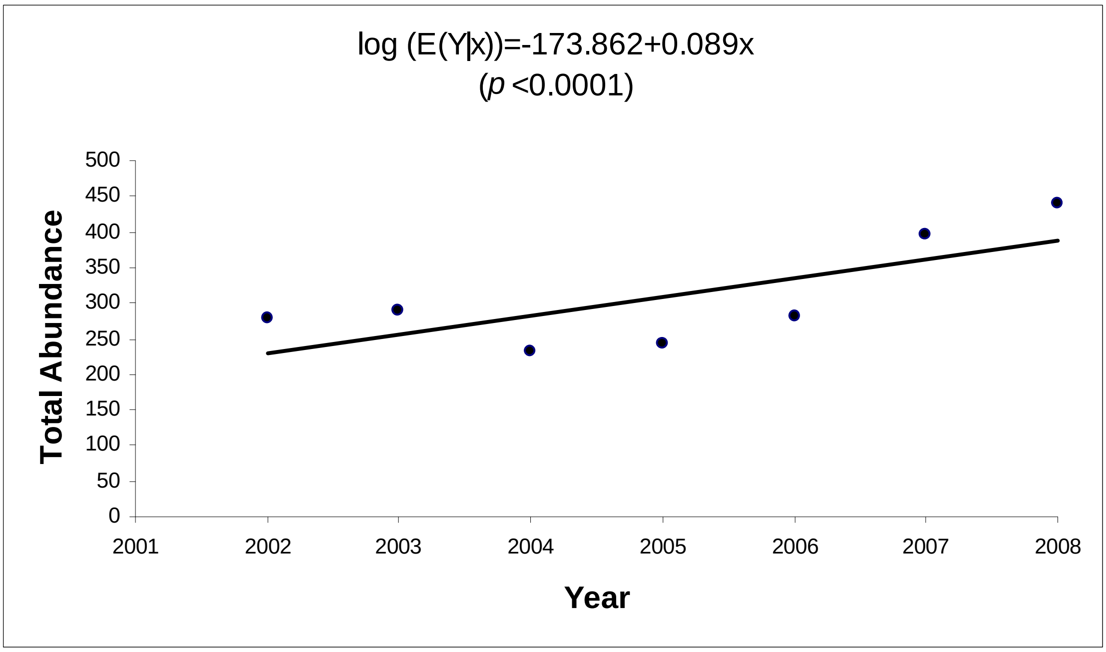

Figure 1. Relative Abundance of Resident Species at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

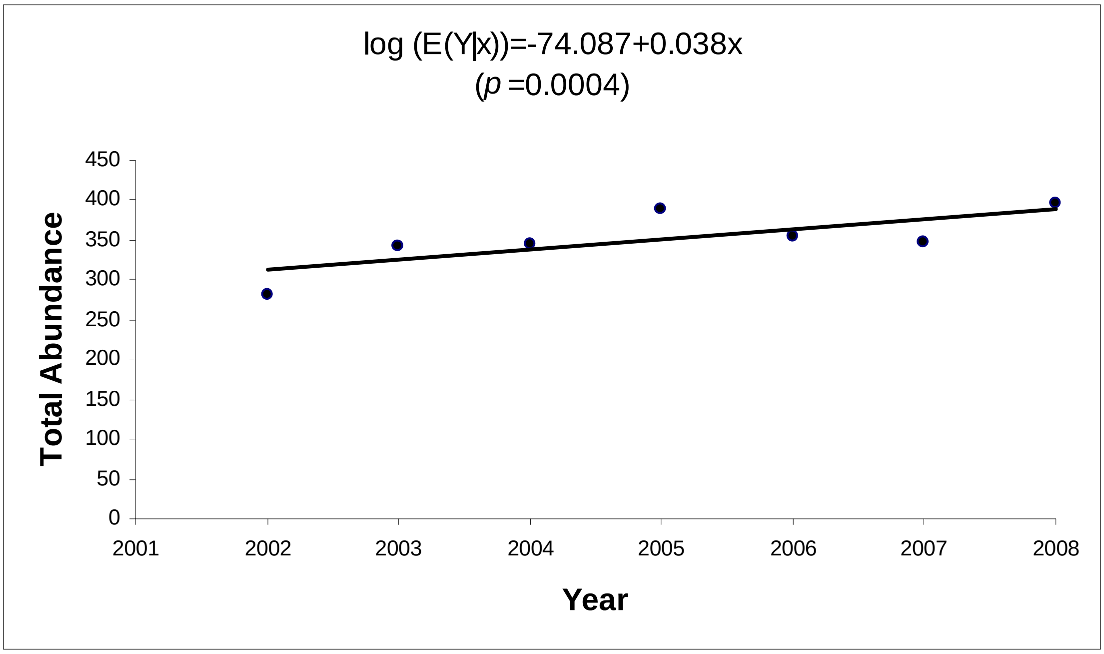

Figure 2. Relative Abundance of Short-distance Migratory Species at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX D: BIRD GUILD TOTAL ABUNDANCE (Cont'd)

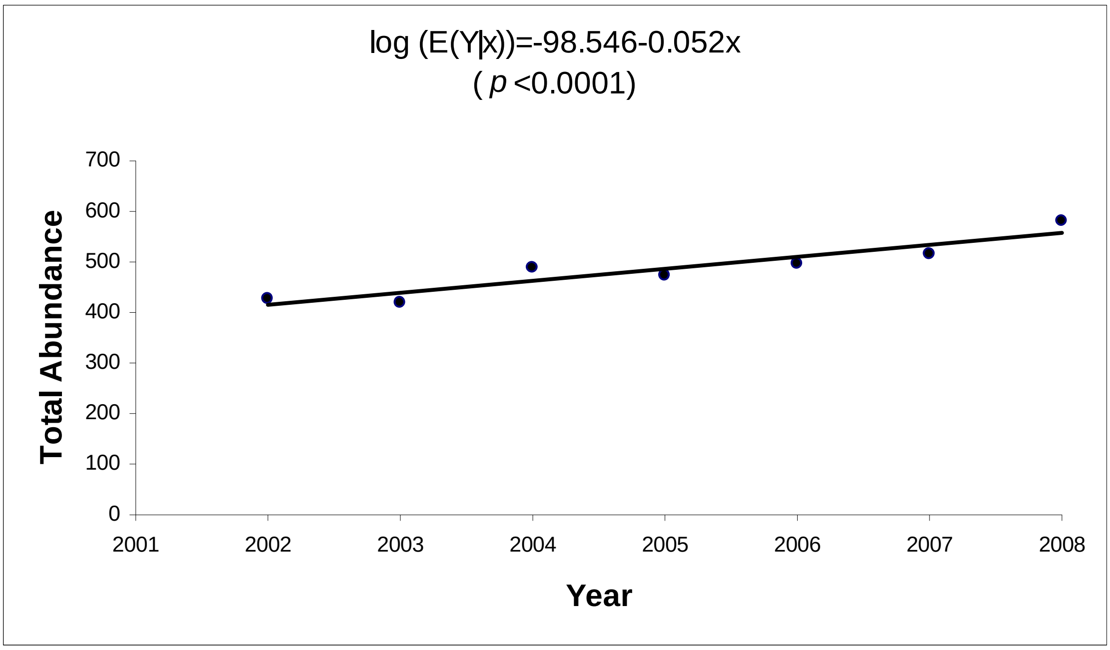

Figure 3. Relative Abundance of Long-distance Migratory Species at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

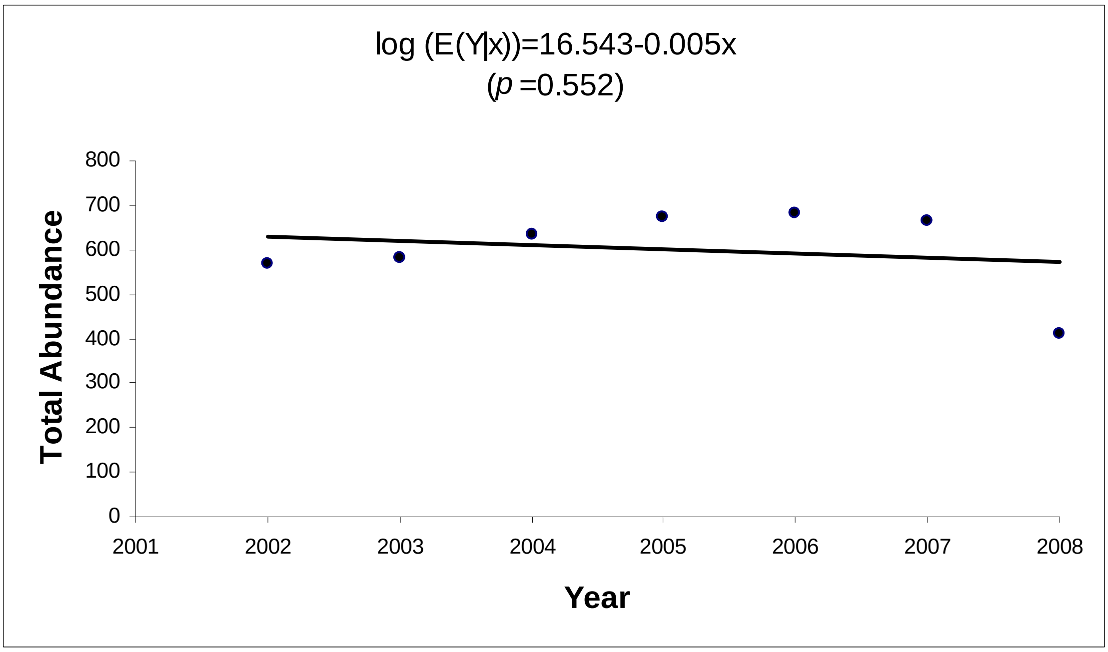

Figure 4. Relative Abundance of Forest Associates at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX D: BIRD GUILD TOTAL ABUNDANCE (Cont'd)

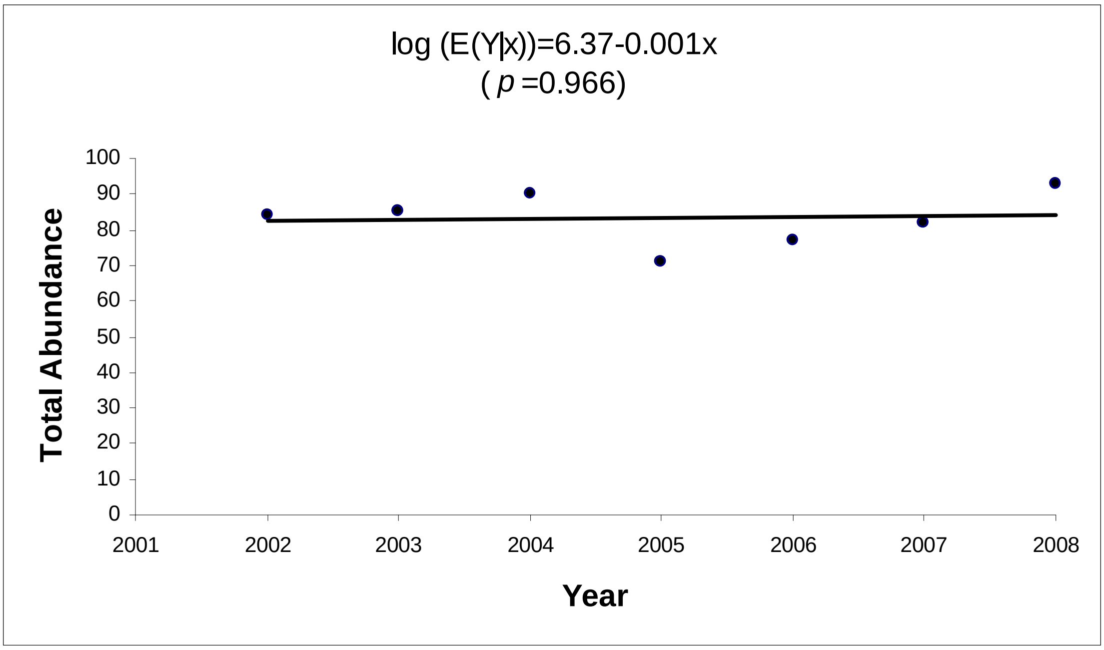

Figure 5. Relative Abundance of Edge/Early Successional Species at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

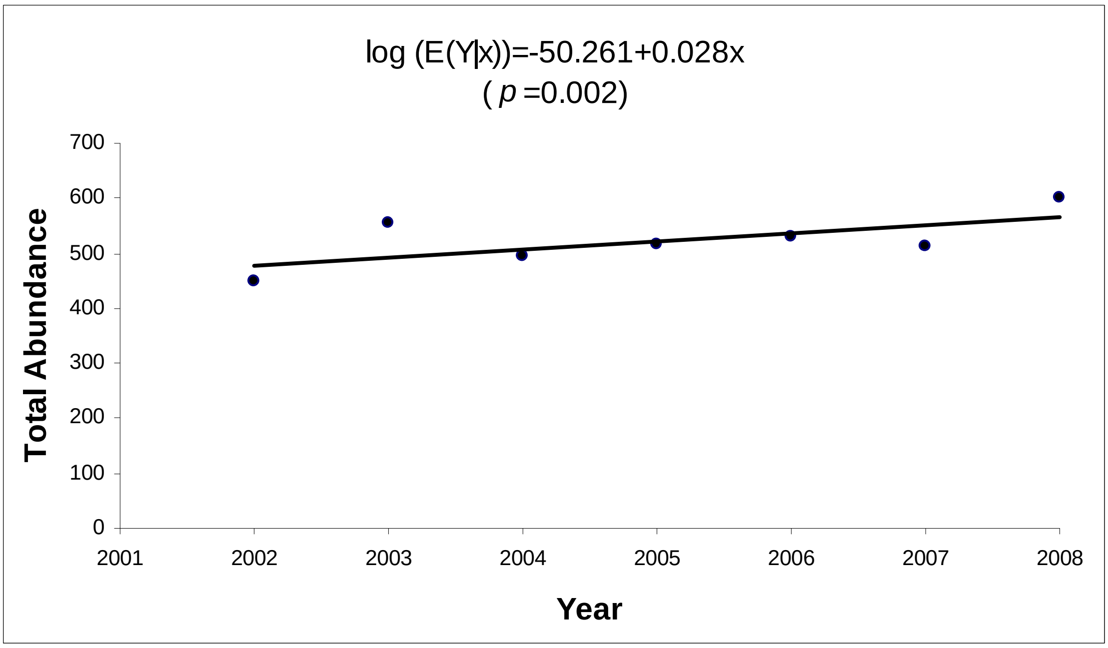

Figure 6. Relative Abundance of Habitat Generalists at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX D: BIRD GUILD TOTAL ABUNDANCE (Cont'd)

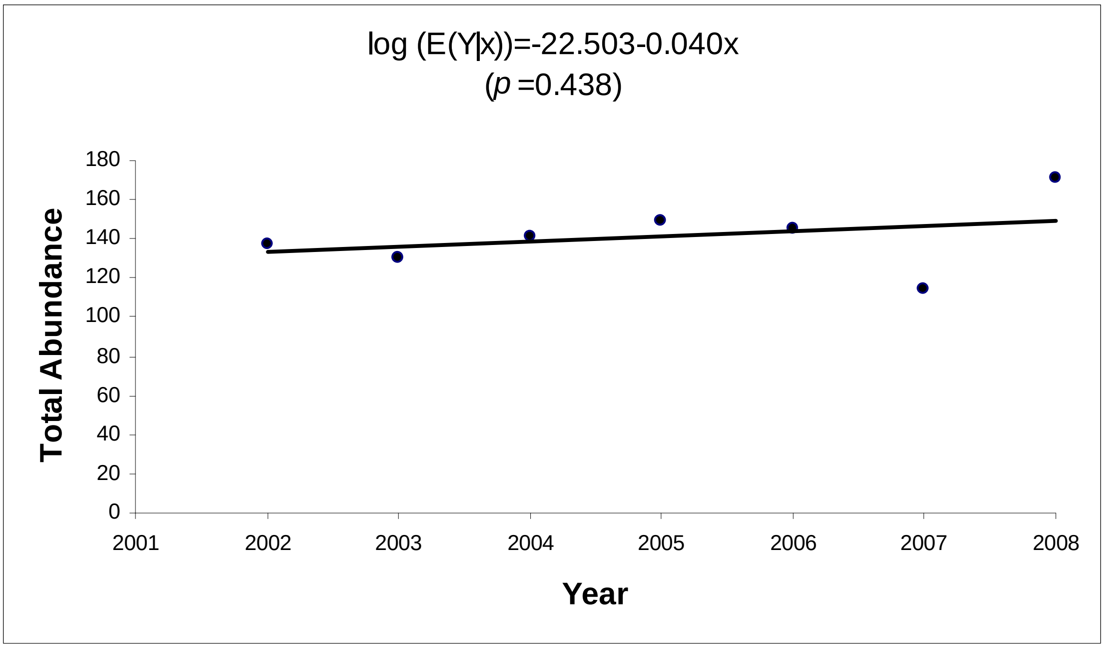

Figure 7. Relative Abundance of Ground Nesting Species at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

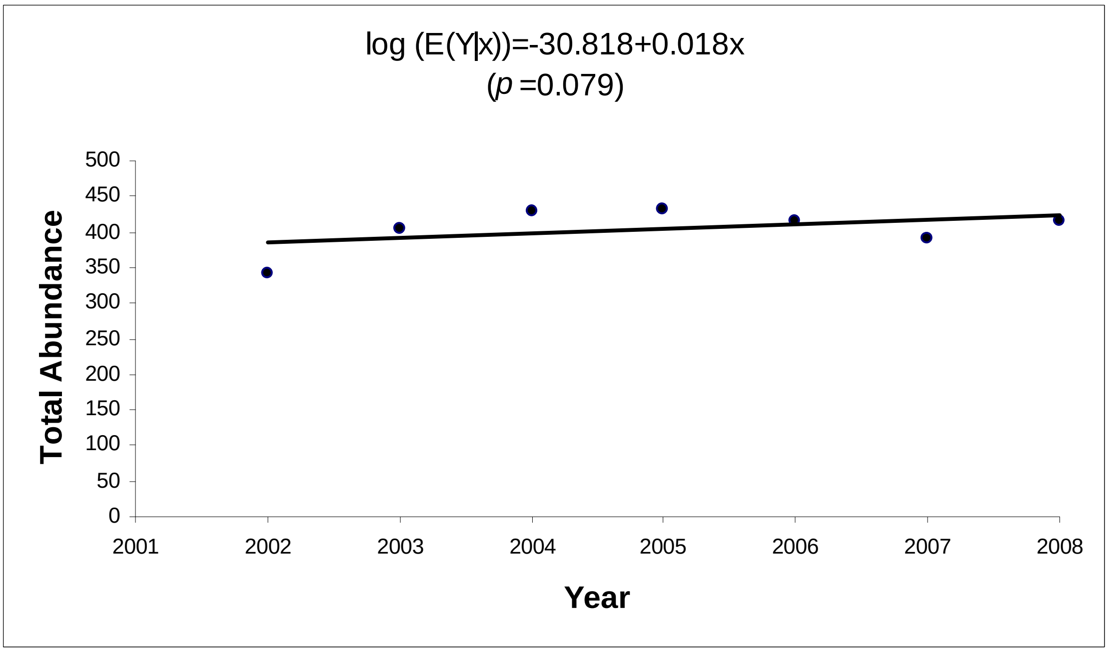

Figure 8. Relative Abundance of Shrub Nesting Species at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX D: BIRD GUILD TOTAL ABUNDANCE (Cont'd)

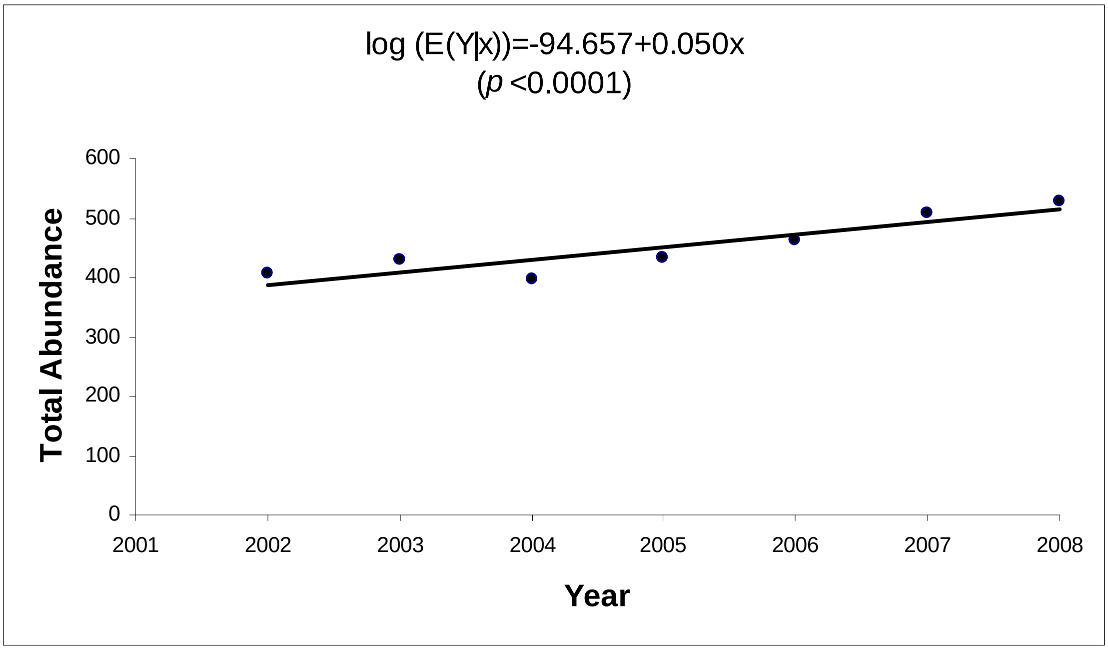

Figure 9. Relative Abundance of Canopy/Sub-canopy Nesting Species at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

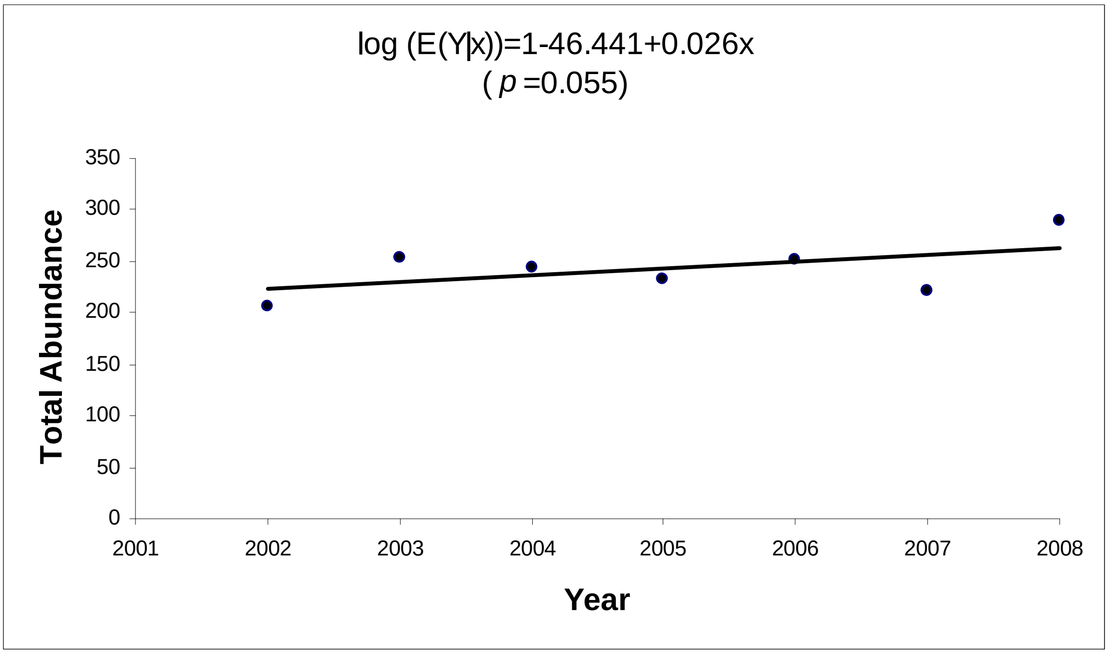

Figure 10. Relative Abundance of Cavity Nesting Species at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX D: BIRD GUILD TOTAL ABUNDANCE (Cont'd)

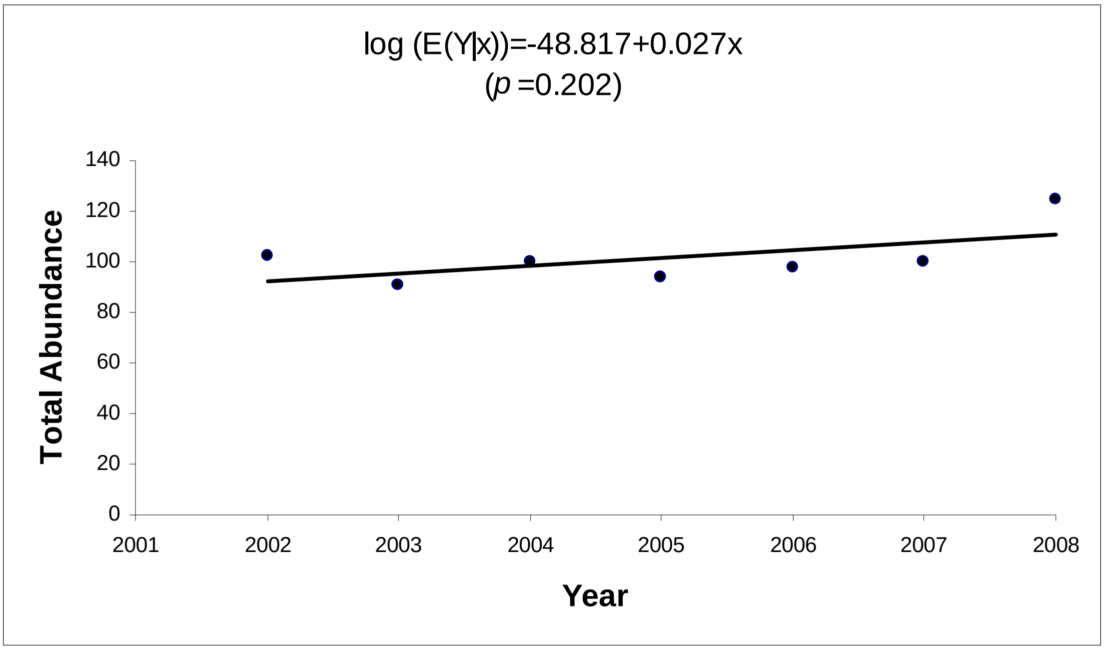

Figure 11. Relative Abundance of Aerial Foraging Species at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX E: BIRD SPECIES TOTAL ABUNDANCE

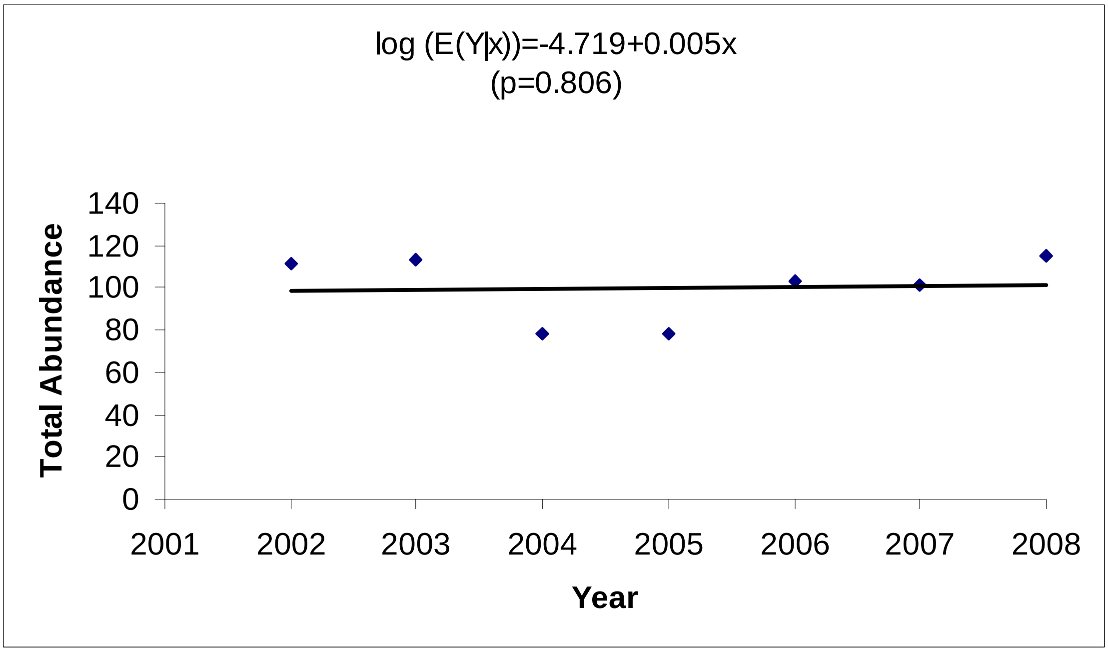

Figure 1. Relative Abundance of American Crow at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

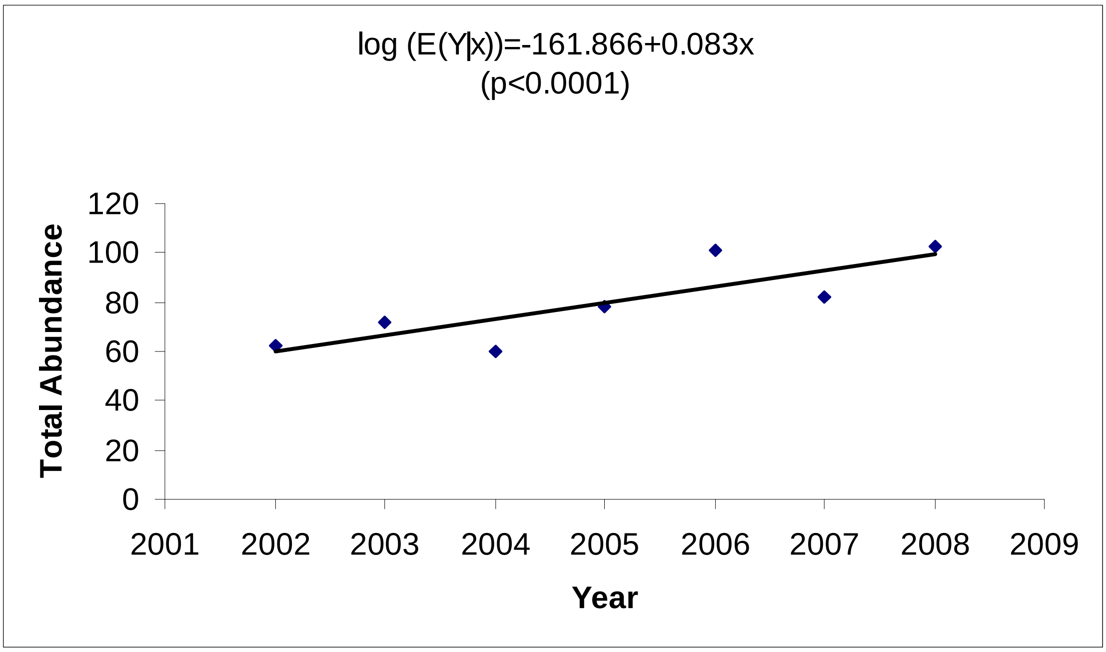

Figure 2. Relative Abundance of American Robin at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX E: BIRD SPECIES TOTAL ABUNDANCE (Cont'd)

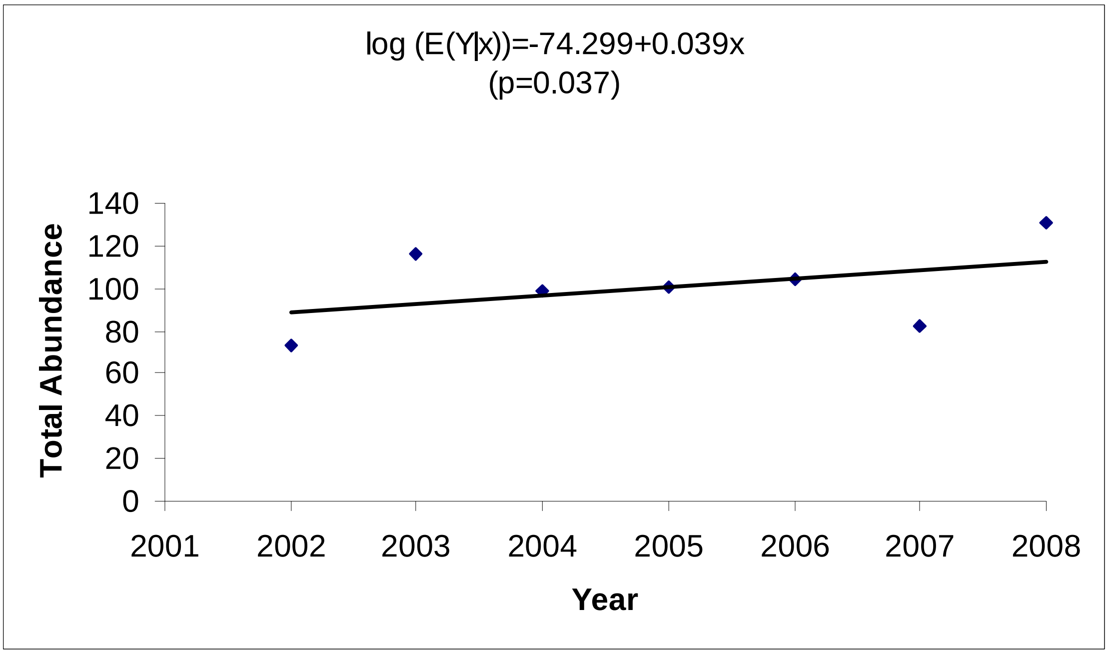

Figure 3. Relative Abundance of Black-capped Chickadee at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

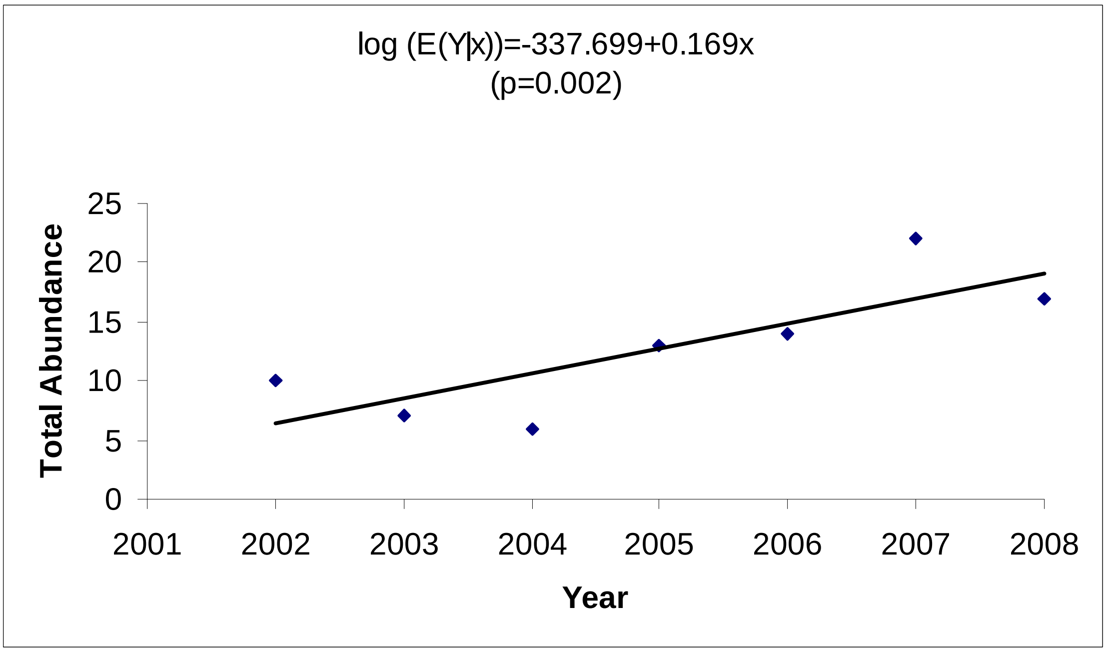

Figure 4. Relative Abundance of Brown-headed Cowbird at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX E: BIRD SPECIES TOTAL ABUNDANCE (Cont'd)

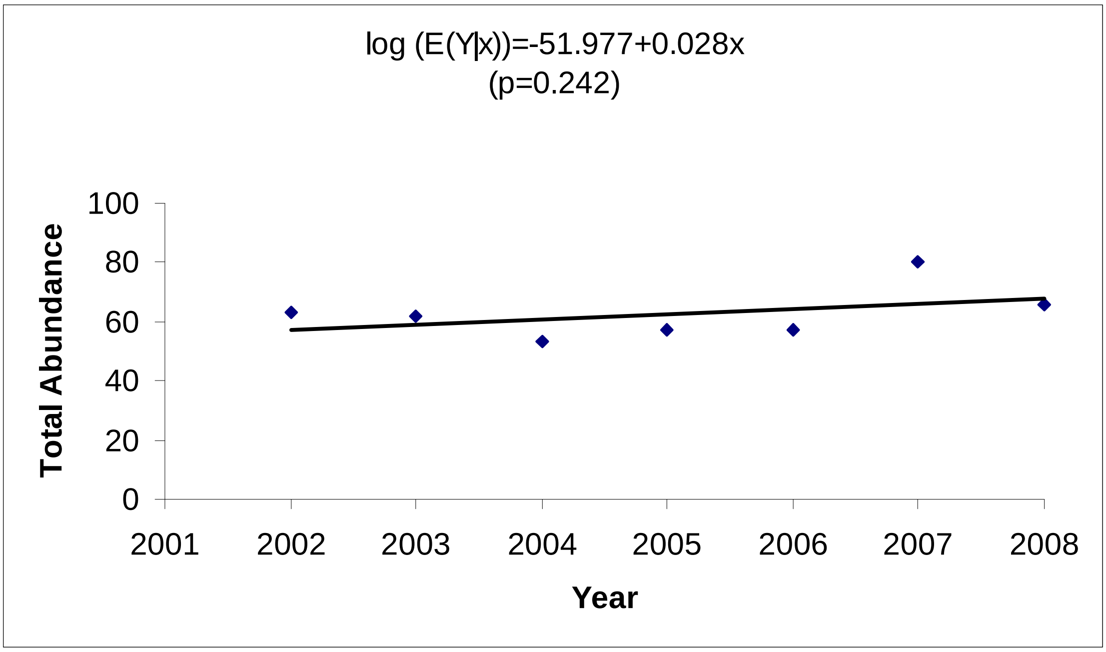

Figure 5. Relative Abundance of Blue Jay at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

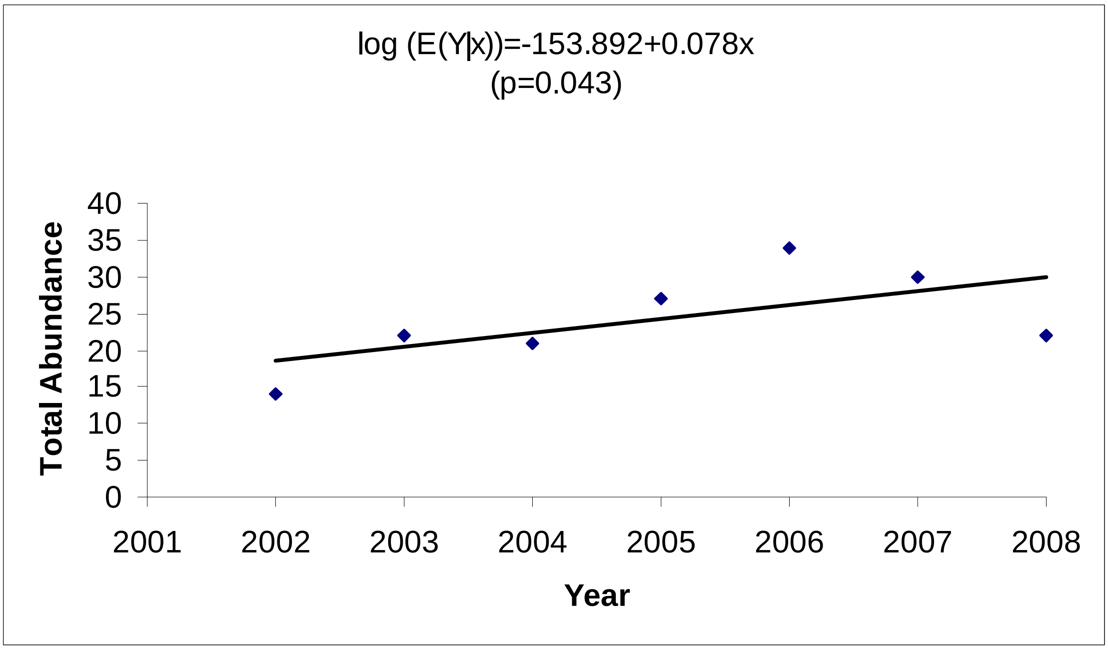

Figure 6. Relative Abundance of Black-throated Green Warbler at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX E: BIRD SPECIES TOTAL ABUNDANCE (Cont'd)

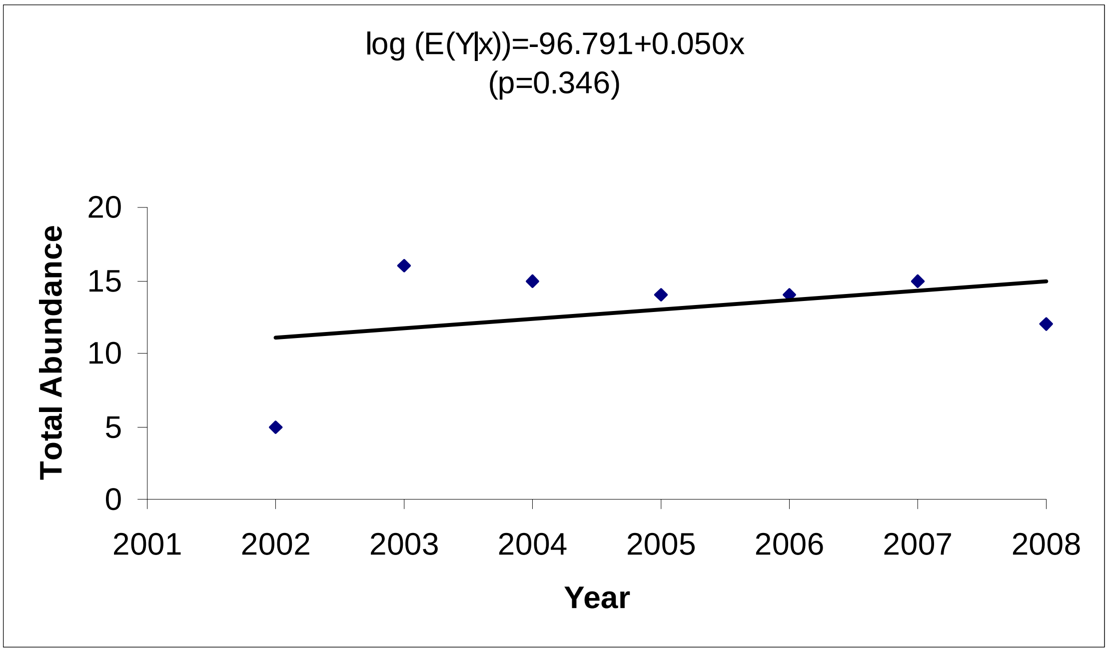

Figure 7. Relative Abundance of Chipping Sparrow at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

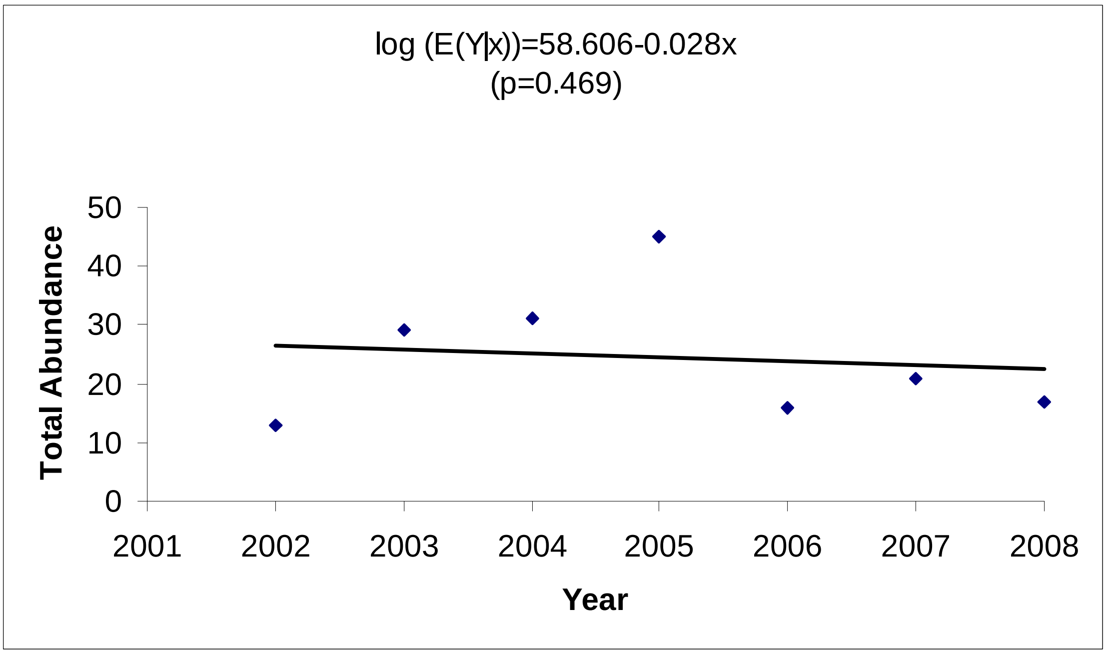

Figure 8.. Relative Abundance of Common Grackle at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX E: BIRD SPECIES TOTAL ABUNDANCE (Cont'd)

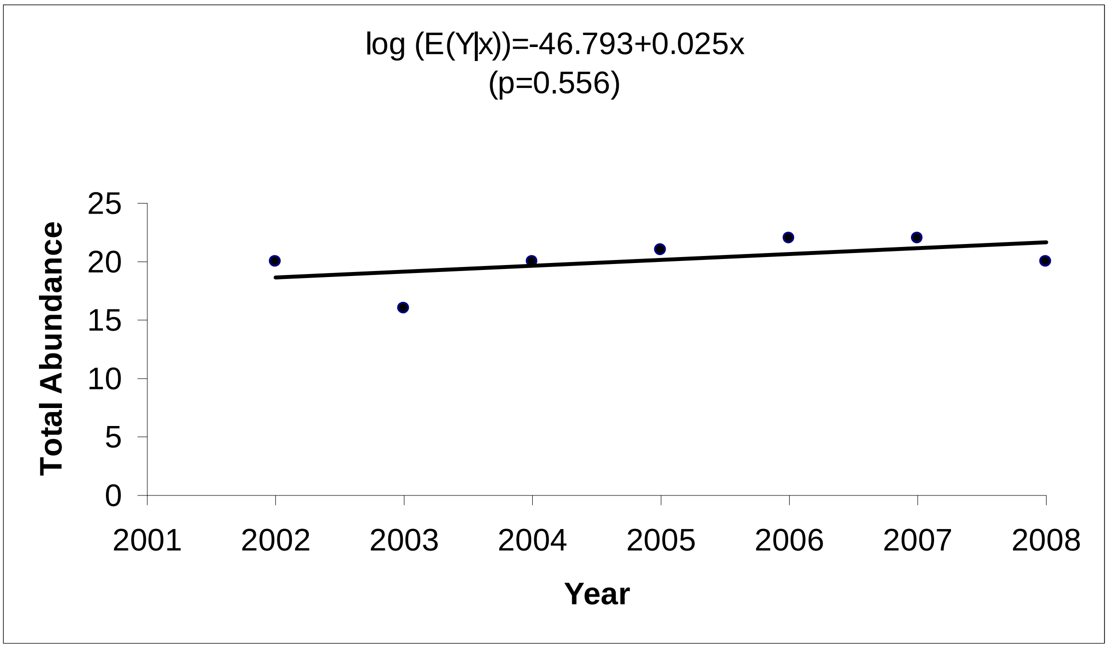

Figure 9. Relative Abundance of Downy Woodpecker at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

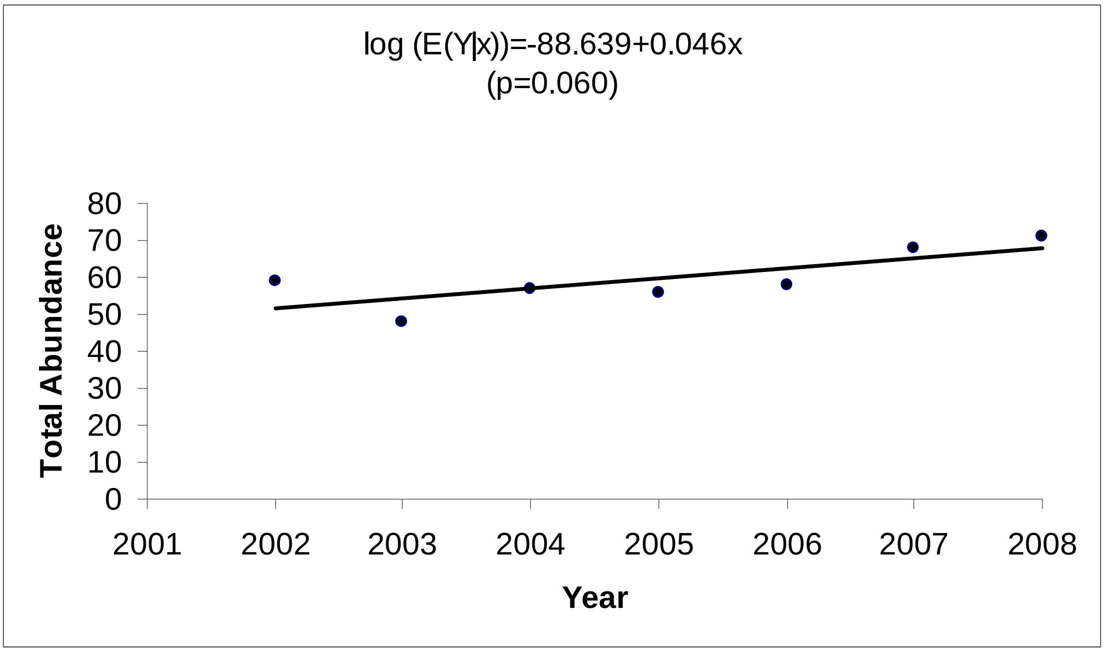

Figure 10. Relative Abundance of Eastern Wood-pewee at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX E: BIRD SPECIES TOTAL ABUNDANCE (Cont'd)

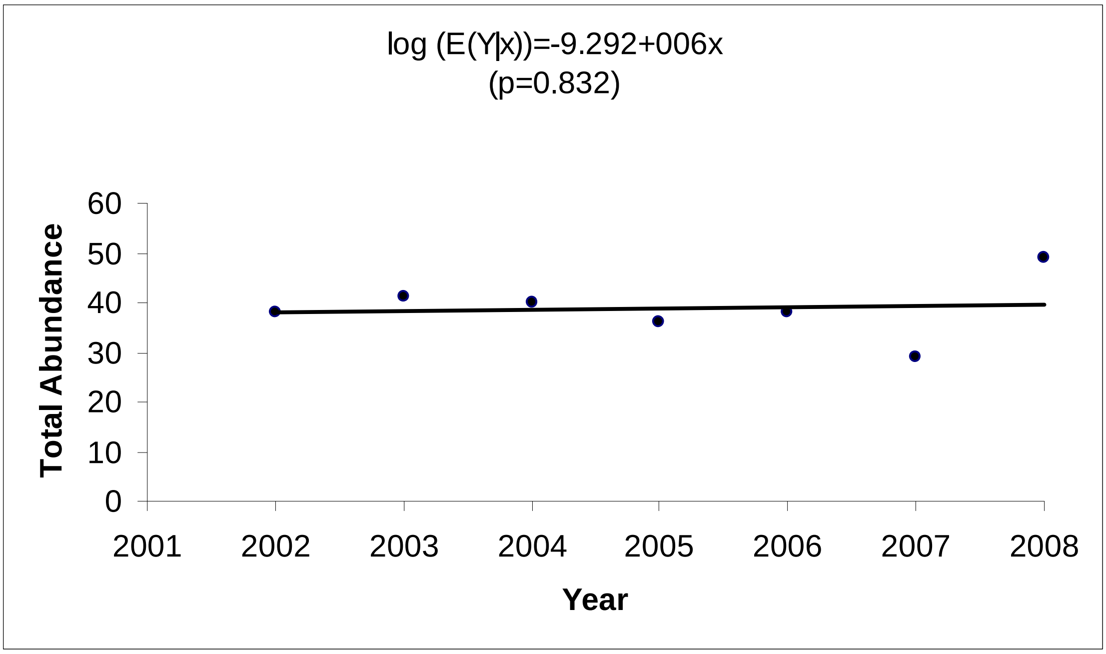

Figure 11. Relative Abundance of Great Crested Flycatcher at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

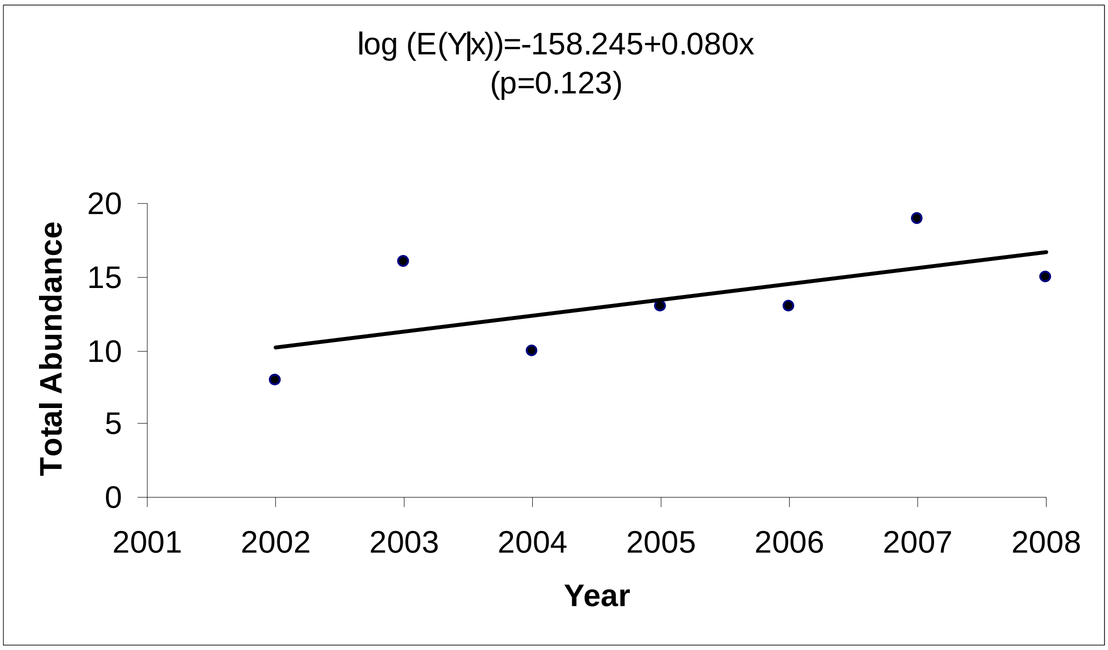

Figure 12. Relative Abundance of Hairy Woodpecker at 25 forest sites in the Credit River Watershed between 2002and 2008. Equation of the regression line and *p*-value provided.

APPENDIX E: BIRD SPECIES TOTAL ABUNDANCE (Cont'd)

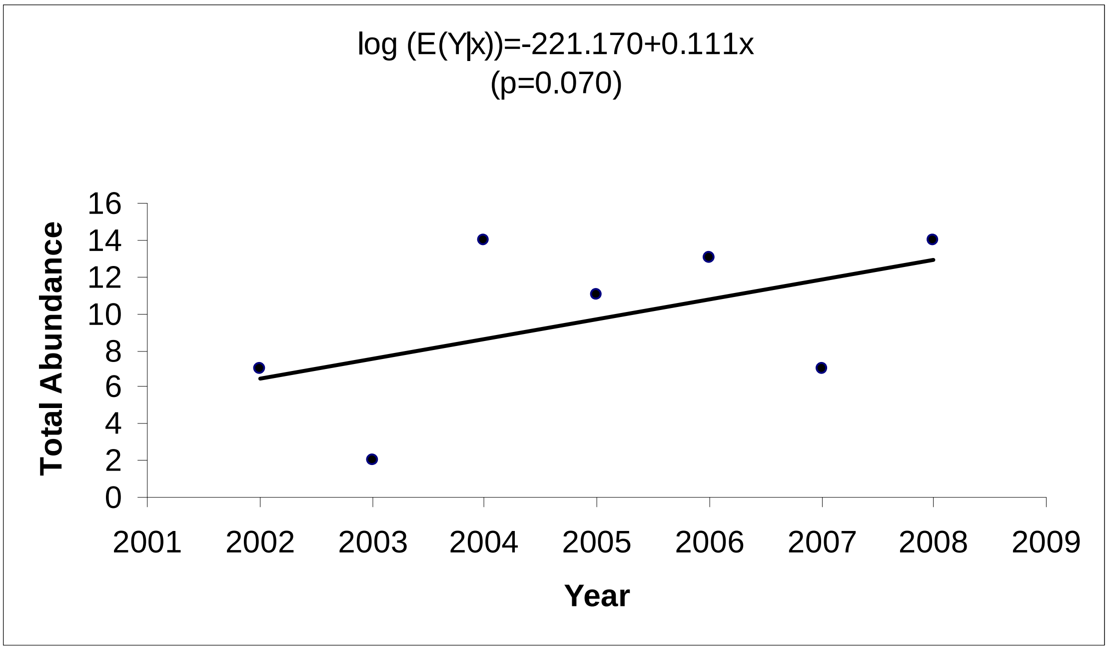

Figure 13. Relative Abundance of House Wren at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

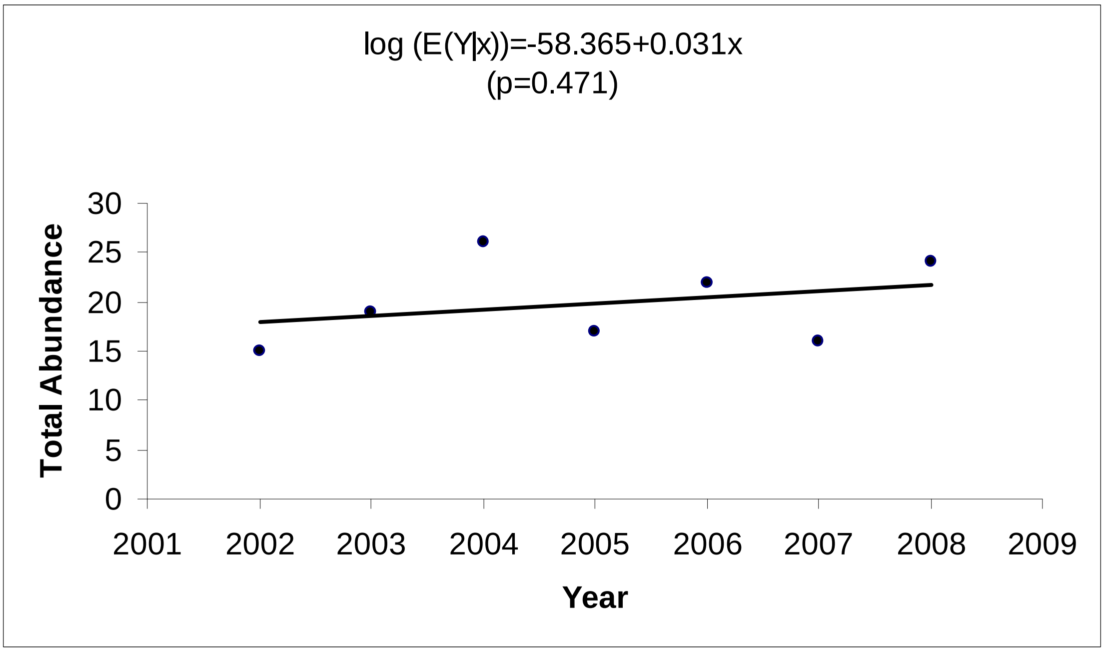

Figure 14. Relative Abundance of Indigo Bunting at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX E: BIRD SPECIES TOTAL ABUNDANCE (Cont'd)

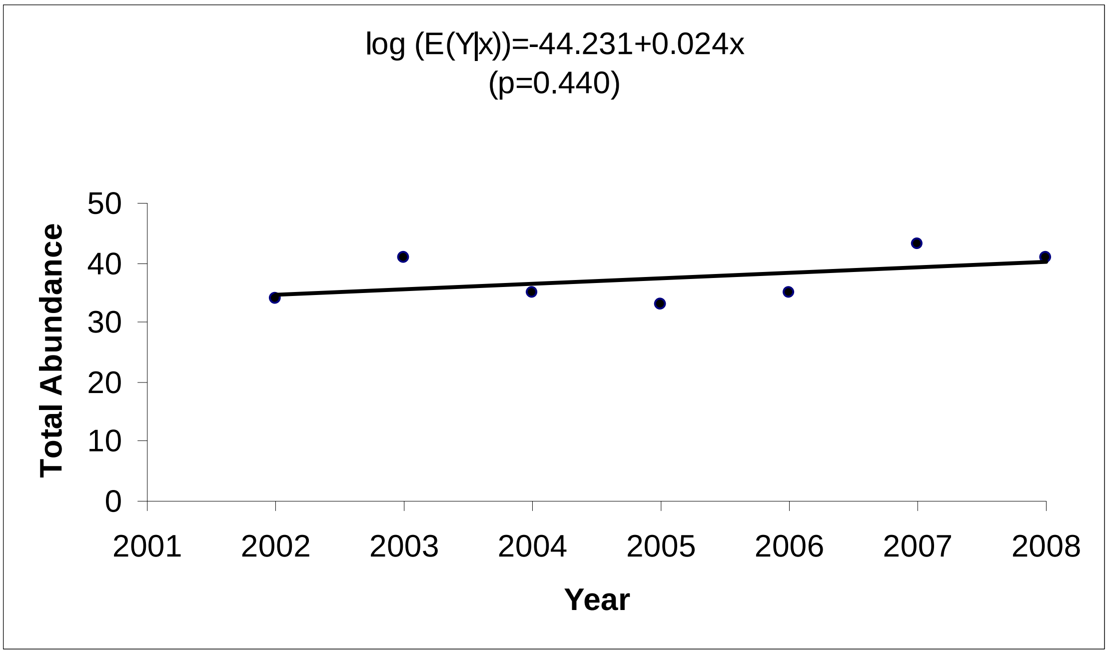

Figure 15. Relative Abundance of Northern Cardinal at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

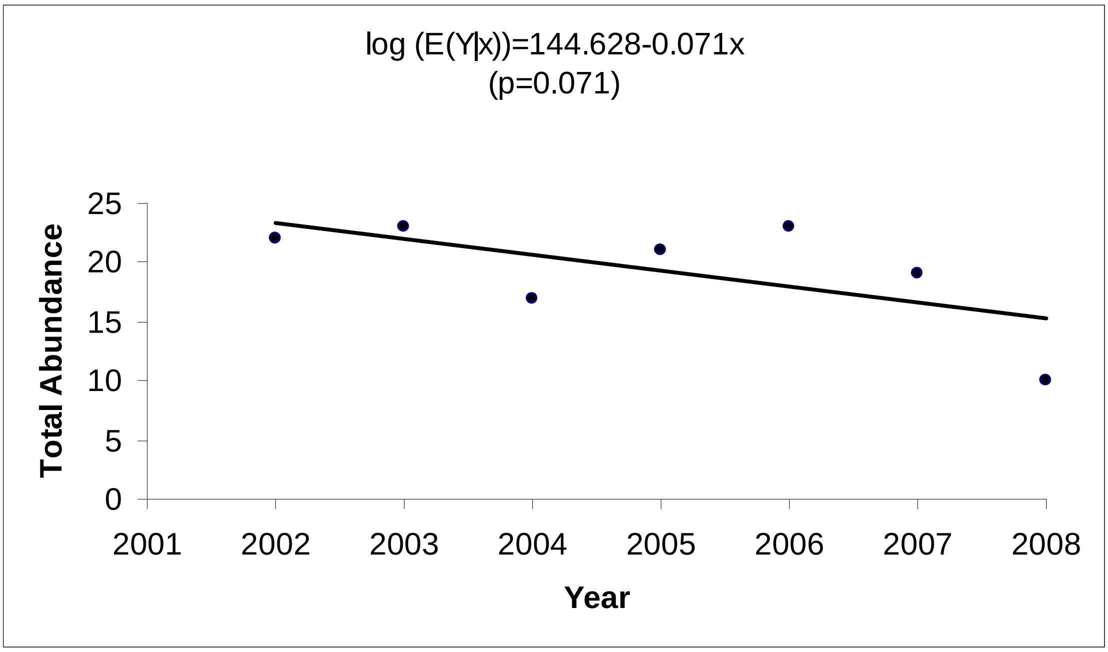

Figure 16. Relative Abundance of Northern Flicker at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX E: BIRD SPECIES TOTAL ABUNDANCE (Cont'd)

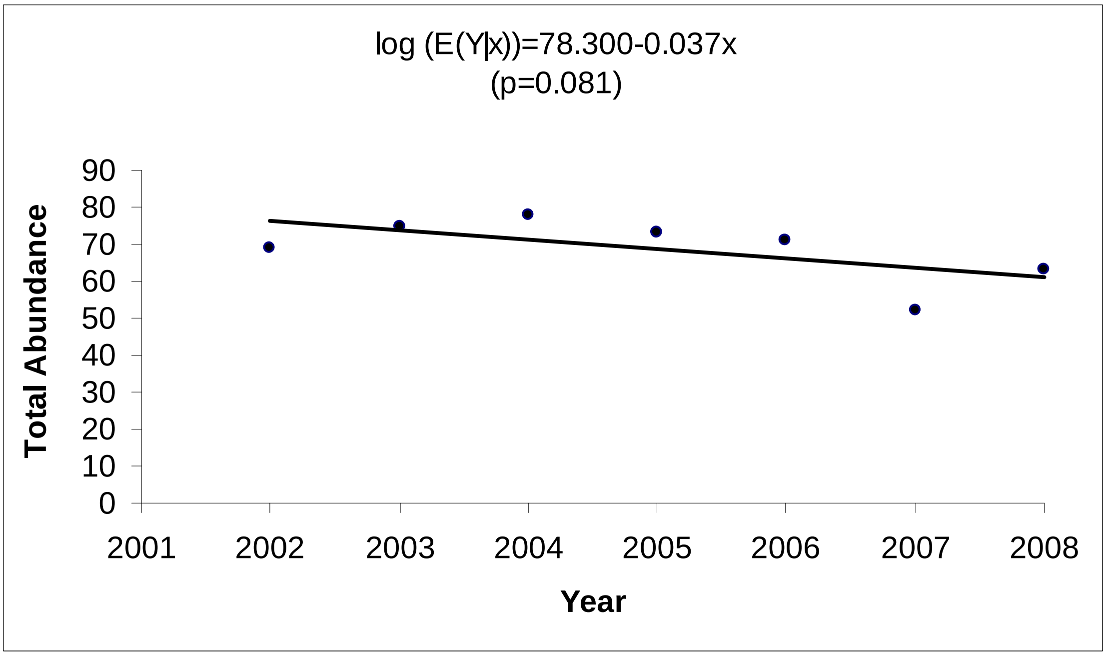

Figure 17. Relative Abundance of Ovenbird at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

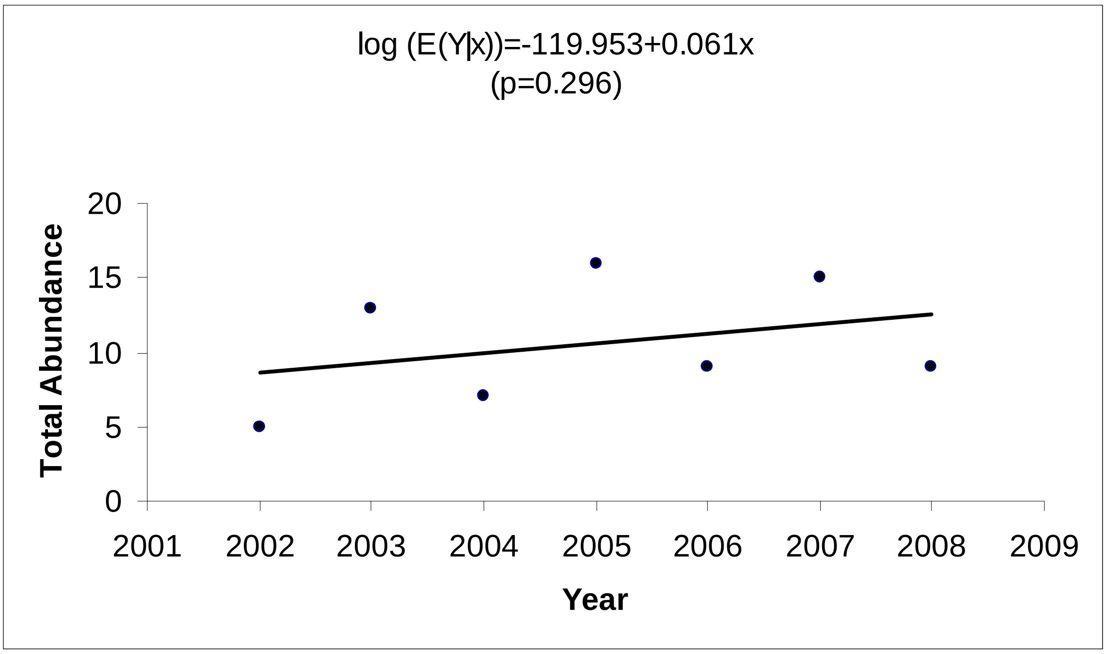

Figure 18. Relative Abundance of Pine Warbler at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX E: BIRD SPECIES TOTAL ABUNDANCE (Cont'd)

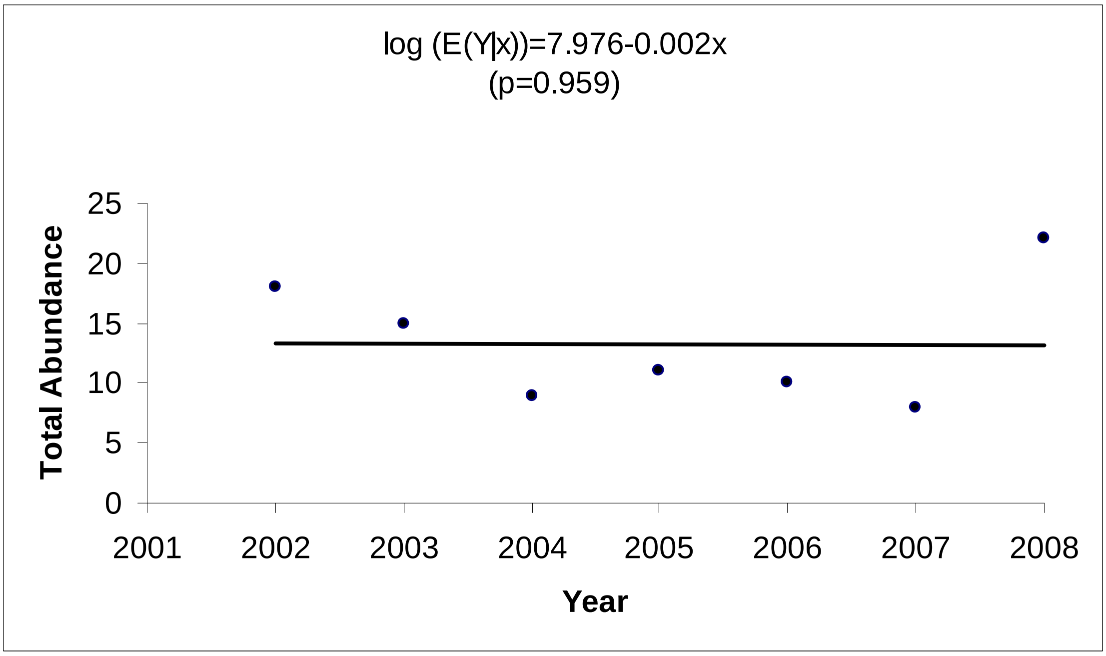

Figure 19. Relative Abundance of Rose-breasted Grosbeak at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

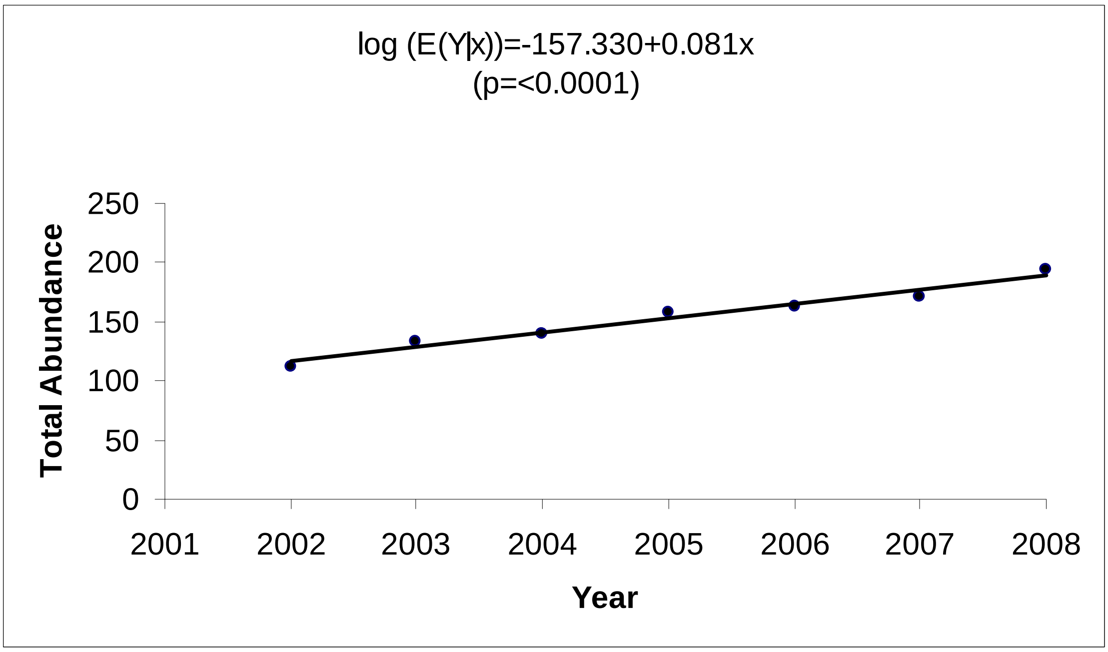

Figure 20. Relative Abundance of Red-eyed Vireo at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX E: BIRD SPECIES TOTAL ABUNDANCE (Cont'd)

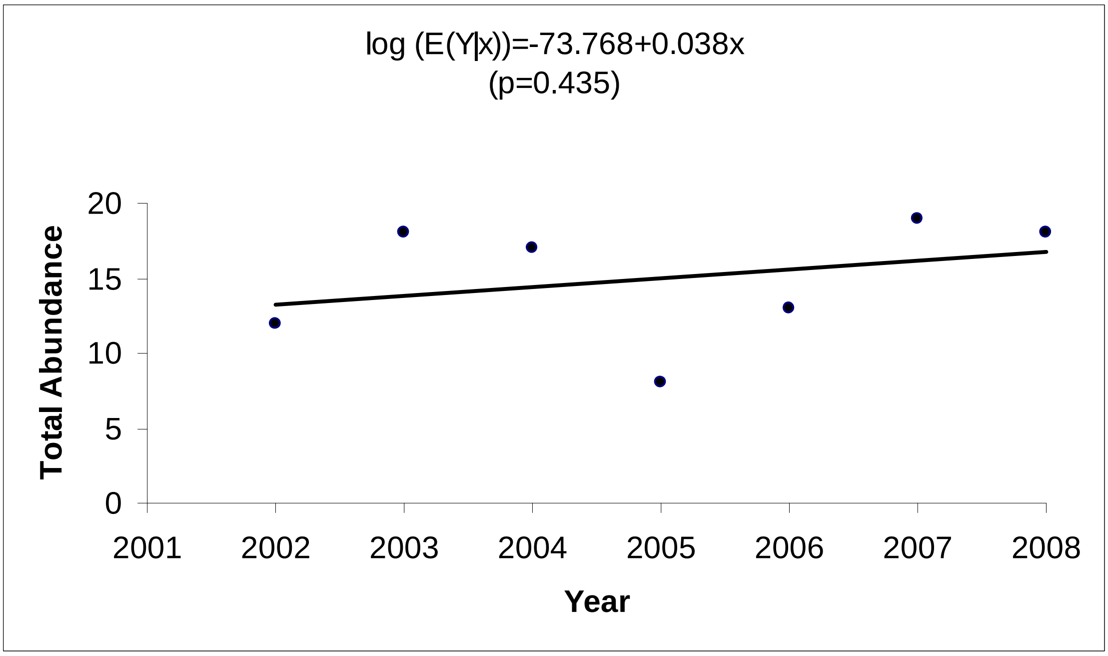

Figure 21. Relative Abundance of Scarlett Tanager at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

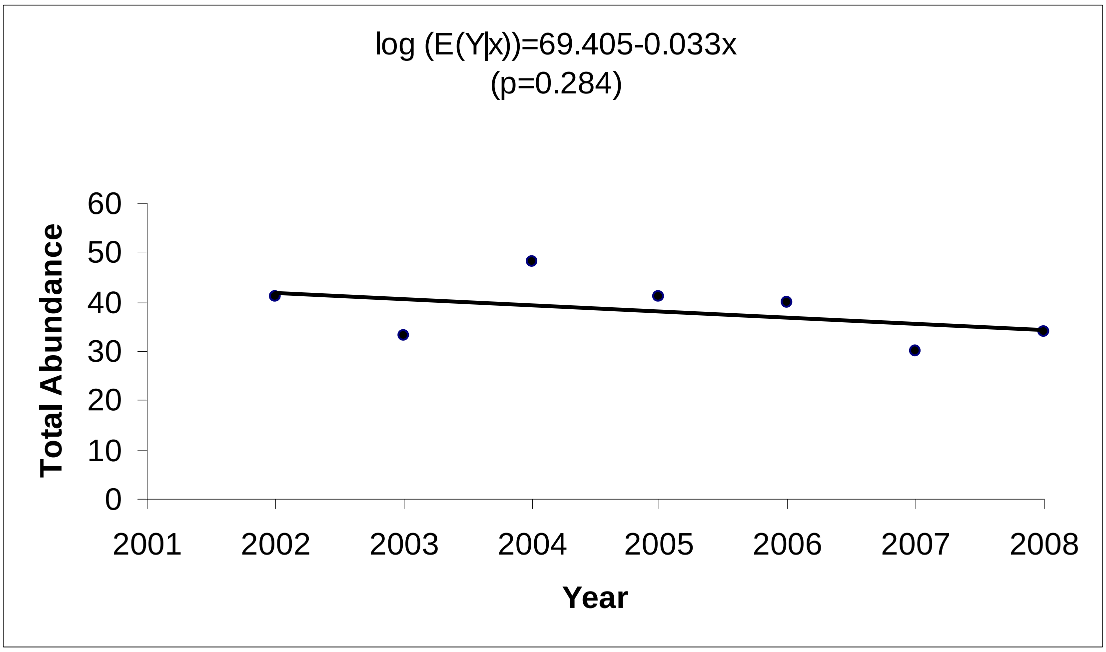

Figure 22. Relative Abundance of Song Sparrow at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX E: BIRD SPECIES TOTAL ABUNDANCE (Cont'd)

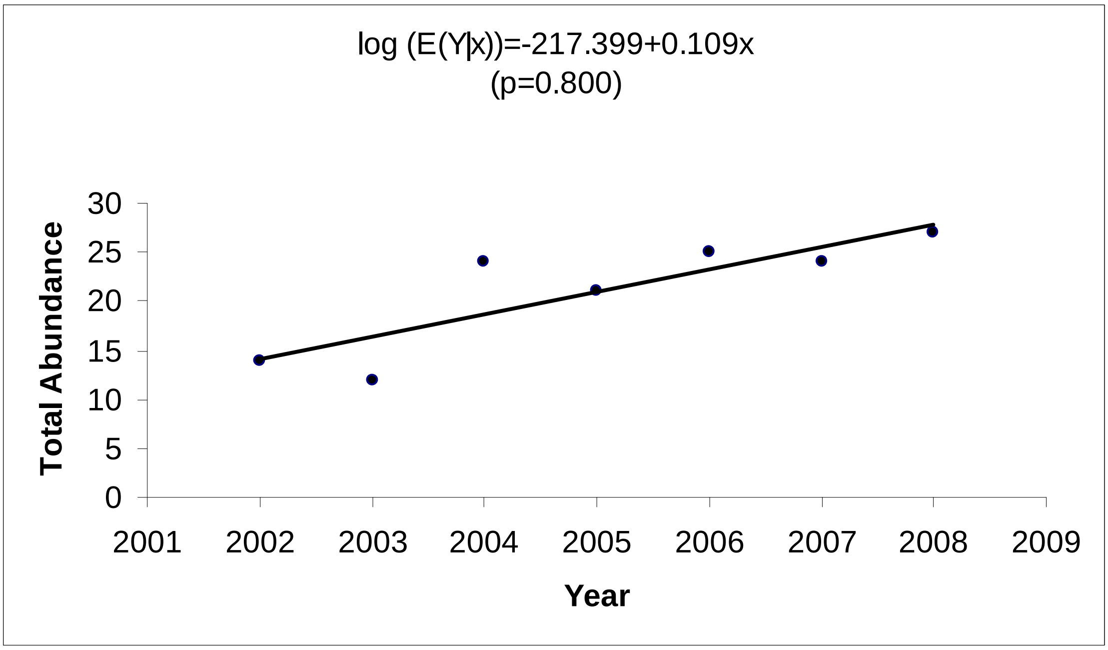

Figure 23. Relative Abundance of Veery at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

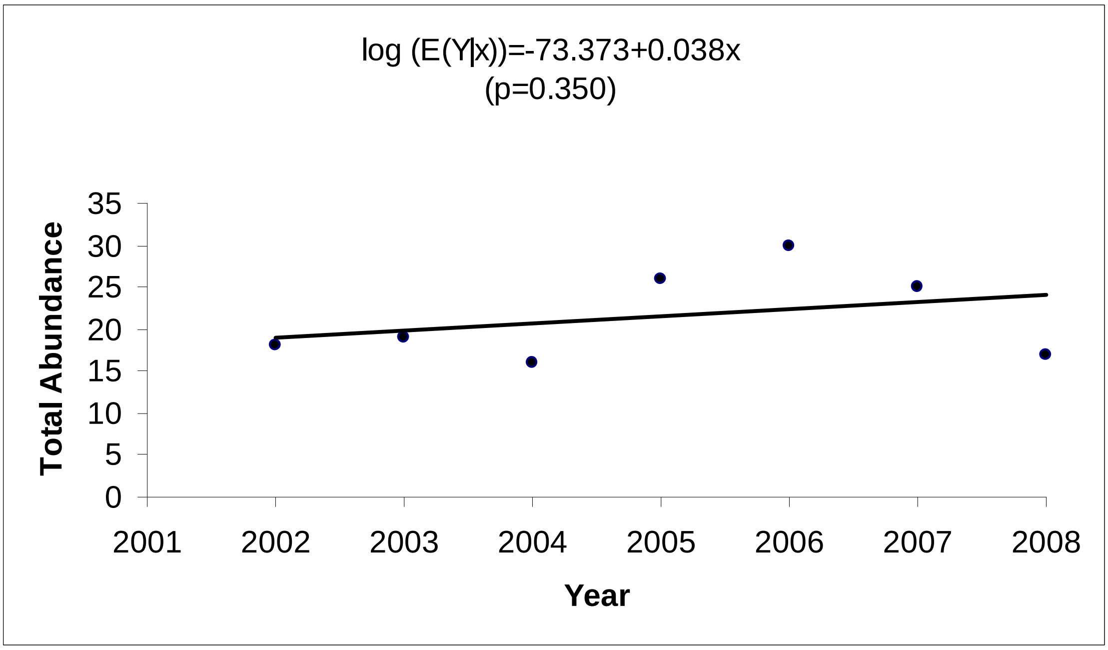

Figure 24. Relative Abundance of White-breasted Nuthatch at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

APPENDIX E: BIRD SPECIES TOTAL ABUNDANCE (Cont'd)

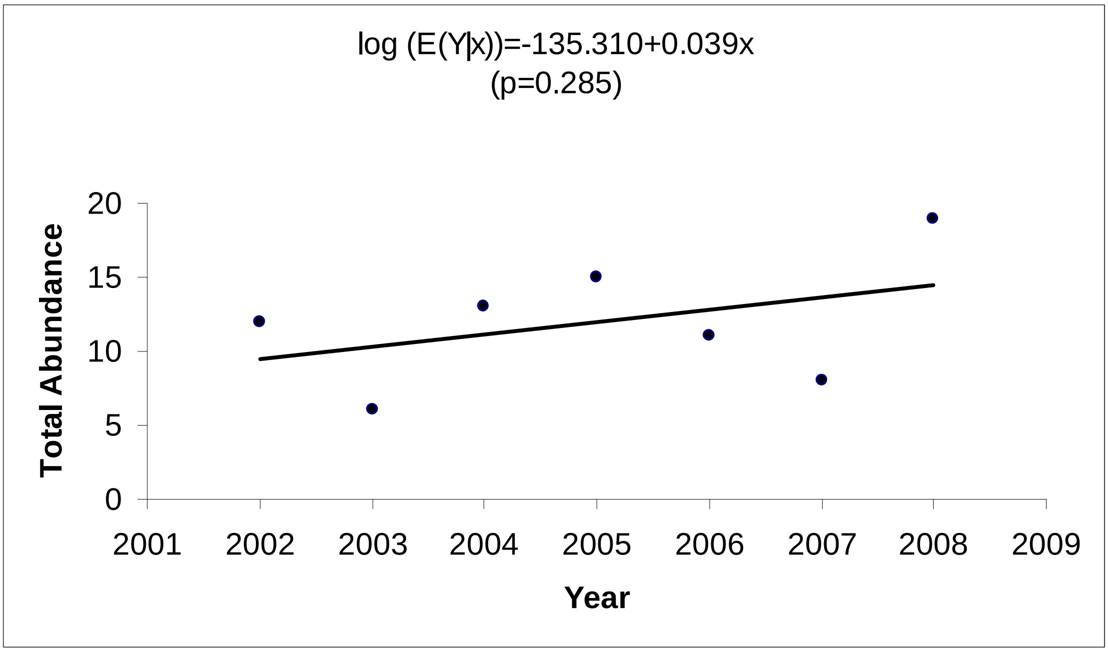

Figure 25. Relative Abundance of Winter Wren at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.

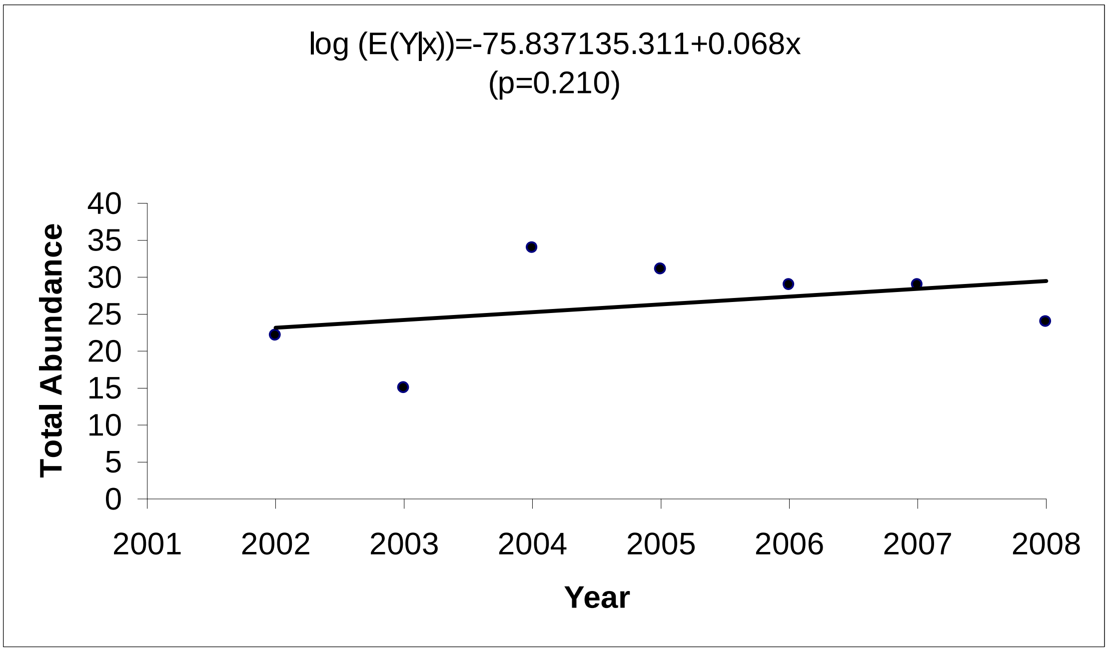

Figure 26. Relative Abundance of Wood Thrush at 25 forest sites in the Credit River Watershed between 2002 and 2008. Equation of the regression line and *p*-value provided.