University of Alberta

FACTORS AFFECTING BIRD POPULATIONS IN THE CITY OF EDMONTON, ALBERTA.

By

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DEDICATION

Quiero dedicar esta tesis a las personas que más he

echado de menos mientras la llevaba a cabo:

Mi familia.

No sólo habéis sido el origen de mi pasión por

la biología, sino que además habéis confiado

siempre en mis locas decisiones sin pedirme

explicaciones de ningún tipo.

Muchas gracias.

ABSTRACT

Urbanization is a major cause of habitat loss and fragmentation and native wildlife has to adapt to this deteriorated environment to survive. In winter and spring 2004, I surveyed birds in 36 30 ha sites located around Edmonton, Alberta that varied in distance to forest and local characteristics (e.g., vegetation, feeders and cats). I used Redundancy Analyses to assess the relative effect of local habitat *versus* landscape structure on the overall bird community and generalized linear models to analyze factors influencing individual resident species in winter and spring. In both analyses, stand-level variables seem to be better predictors of abundance than landscape composition. Number of coniferous trees, tall deciduous trees, and feeding stations were the most important variables, whereas distance to forest or agricultural areas, traffic levels, and cat and dog abundance were not predictors of abundance. I discuss the relevance of my findings for bird conservation in Edmonton.

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CHAPTER 1. THESIS INTRODUCTION

Human settlements are expanding all over the world (Melles *et al.* 2003). The majority of urban areas are located near large bodies of water (World Resource Institute 1996). These riparian and coastal ecosystems contain high species diversity (Knopf *et al.* 1988, Gregory *et al.* 1991, Naiman and Decamps 1997), which is threatened by continuous human expansion (Nilsson and Dynesius 1994). The main consequence of human development is habitat fragmentation and species endangerment (Czech and Krausman 1997). The remaining natural habitats are continuously being disturbed and modified by increasing areas of non-vegetated surfaces (Beissinger and Osborne 1982, Germaine *et al.* 1998). In addition, mature and native plants are being replaced by younger exotic ornamentals (Beissinger and Osborne 1982).

Many authors have examined the effects of urbanization on wildlife, especially birds (Campbell and Dagg 1976, DeGraaf 1991, Edgar and Kershaw 1994, Melles *et al.* 2003). Overall, urban alteration decreases bird species diversity and increases the density of a few species, primarily exotic ones (Marzluff *et al.* 1998). In residential areas, the density of people, dogs and traffic generate a level of disturbance which can be intolerable for many sensitive species (Busnel and Fletcher 1978, Reijnen *et al.* 1995, Miller *et al.* 1998, Randler 2003). Urbanization also alters predator assemblages. The abundance of large native carnivores decreases, while numbers of domestic cats increases (Crooks and Soule 1999, Baker *et al.* 2005), which can reduce density of bird species nesting and feeding on the ground and in low shrubs (Emlen 1974, Coleman *et al.* 1997).

Despite the negative effects, urban areas contain some resources for birds. Vegetation along residential streets, although dominated by exotic species, might provide a source of food, roosting sites and refuge for bird species (Rosenberg *et al.* 1987, Bovey 1988). Feeding stations, nesting boxes and garbage provided by humans can improve birds' reproductive success and survival (Brittingham and Temple 1992, Marzluff 1997, Harper *et al.* 2005), increasing the attractiveness of urban habitats (Erskine 1992, Yaukey 1996). However, bird feeders and bird boxes might also increase the transmission of diseases (Chace and Walsh 2006, Marzluff *et al.* 1998) and improve conditions for omnivorous, granivorous, scavengers, and cavity nesting species (Emlen 1974, Lancaster and Rees 1979, Beissinger and Osborne 1982, Rosenberg *et al.* 1987).

Higher temperatures found in large cities, together with winter feeding, might explain why some species such as Blue Jays (*Cyanocitta cristata*) and Merlins (*Falco columbarius*) are currently overwintering farther north than they did historically (Ferguson *et al.* 2000).

My study took place in the City of Edmonton (53°30'N, 113°30' W), Alberta. Edmonton originated in 1795 as a fur trading fort built by the Hudson's Bay Company next to the North Saskatchewan River (MacGregor 1967). Although Edmonton's population and economy grew considerably through the nineteenth and first half of twentieth century, its main development did not occur until 1947 when oil and gas was discovered approximately 17 miles south of the city (MacGregor 1967, Hassbring 1969).

Since 1915 the City of Edmonton has established a series of policies in order to reserve the river valley and ravines for recreation (Bedford 1976, Havrelock and Edwards 1990). As a consequence of this early protection, the North Saskatchewan

River System is currently the largest continuous urban park in North America. It covers an area of 7400 hectares of "semi-natural" parkland including three major and 19 secondary ravines (Edmonton Parks & Recreation 1992), playing an important role in providing habitat for many native bird species (e.g. Pileated Woodpeckers (*Dryocopus pileatus*), owls and ground and shrub nesters), which probably would not be present in an urban environment otherwise.

Beyond the limits of the river valley and associated ravines, no other major forested parks are present; however, wooded streets in residential areas can act as alternative habitat for many bird species (Fernandez-Juricic 2001, Melles et al. 2003). Over 65% of Edmonton dwellings consist of single-family houses which are usually surrounded by front and backyards containing trees and shrubs (Community Services Department 2004, City of Edmonton). Common tree species found in Edmonton's yards are manitoba maple (*Acer negundo*), mountain ash (*Sorbus aucuparia*), spruces (*Picea spp.*), poplars (*Populus spp.*), birch (*Betula papyrifera*), green ash (*Fraxinus pennsylvanica*), cherry and plum (*Prunus spp.*), and apple trees (*Malus spp.*). Among the shrubs, cedar (*Thuja spp.*), caragana (*Caragana arborescens*), cotoneaster (*Cotoneaster acutifolia*) and lilac (*Syringa spp.*) are the most abundant (Waldron and Dyck 1973). In the more mature neighbourhoods there are also deciduous trees, mostly white elms (*Ulmus americana*), on the boulevards adjacent to front streets.

Throughout the city of Edmonton there is an average of 4.82 nest boxes km^{-2} of street and 4.79 feeders km^{-1} of street (Tablado-Almela 2006, Chapter 2), corresponding to one bird box and one bird feeder every 14 houses. According to data from the Planning and Development Department (2004) of the City of Edmonton, the number of licensed cats in Edmonton is 9.5cats km^{-1} of street. However. only a small proportion of them might be outdoors, especially in the cold winter months.

While many authors have already studied bird populations in residential areas (Campbell and Dagg 1976, Lancaster and Rees 1979, DeGraaf 1991, Edgar and Kershaw 1994), only a few have investigated the effect of nearby “natural” habitat on birds of urban streets (Fernandez-Juricic 2000, Melles *et al.* 2003). The structure of the city of Edmonton around a bisecting parkland (i.e. River Valley System), provides an ideal scenario to evaluate simultaneously the effect of local and landscape features on the bird community in Edmonton neighbourhoods.

In chapter 2, I present the results of my two main objectives. First, I assessed the relative importance of local-level habitat *versus* landscape structure on the bird community found in residential areas of Edmonton. Secondly, I examined seven resident bird species to obtain information about specific variables influencing their winter and spring distributions and abundance. Finally, I discuss the relevance of my results to urban planning that will promote enhancement of bird biodiversity in the city.

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CHAPTER 2. EFFECTS OF LANDSCAPE AND LOCAL HABITAT ON AN URBAN BIRD COMMUNITY IN EDMONTON, ALBERTA.

INTRODUCTION

As world populations grow, humans are concentrating in urban areas (Marzluff *et al.* 2001). The United Nations estimated that by 2050, the global urban population would equal today's total population (~6.5 billion; United Nations 1996). In developed countries, cities are growing much faster in area than in population size (Marzluff *et al.* 2001). Urbanization is one of the most important causes of habitat loss, fragmentation and endangerment of birds and other wildlife (Czech and Krausman 1997). Many natural habitats are replaced by non-vegetated surfaces, such as roads or buildings (Beissinger and Osborne 1982, Germaine *et al.* 1998) and snags (crucial for cavity nesters) are cut down, decreasing vegetative cover used by native birds to breed and take refuge. Noisy roads can represent a barrier for some birds (St. Clair 2003), reducing movement and some species also avoid habitat near roads due to noise (Reijnen *et al.* 1995). Traffic, construction and aircraft noises can cause energy loss, decreased feeding opportunities and habitat avoidance by wildlife (Busnel and Fletcher 1978).

Food and predation pressure are also altered by urbanization. Human garbage increases, which can benefit scavenging omnivorous species (Marzluff *et al.* 1998), native plants are replaced by exotic ornamentals, which have fewer insects and seeds (Beissinger and Osborne 1982), and food is added at feeding stations. Additional food can improve birds' reproductive success (Grubb and Cimprich 1990) and winter survival (Jansson *et al.* 1981, Brittingham and Temple 1988, Desrochers *et al.* 1988). However, excessive winter feeding might favour sedentary seed-eating and omnivorous bird species, such as House Sparrows (*Passer domesticus*) and Rock Doves (*Columba livia*), which are already abundant in urban areas (Emlen 1974, Lancaster and Rees 1979, Jokimaki and Suhonen 1998). Predation pressure, especially on ground-nesting and low-shrub foraging species, can be higher in cities due to free-ranging domestic cats (Emlen 1974, Coleman *et al.* 1997). However, in cities with coyotes, medium-sized predators such us domestic cats and foxes are suppressed (Soulé *et al.* 1988), which can improve bird nesting success.

Several authors have focused on these factors to account for bird species' distribution and abundance in residential areas (DeGraaf 1991, Edgar and Kershaw 1994). Some examined bird communities through a gradient of urbanization (Campbell and Dagg 1976, Lancaster and Rees 1979, Blair 1996), while others compared urban and non-urban communities (Emlen 1974, Beissinger and Osborne 1982). While most studies have focused on local factors, few have considered the additional effects on bird populations of the structure of the landscape or the presence of nearby higher quality habitats (Fernandez-Juricic 2000, Melles 2001). For example, urban parks might act as a "source" of birds that occupy marginal habitat along residential streets (Fernandez-Juricic 2001, Melles *et al.* 2003), and wooded strips along streets could improve connectivity for birds (Fernandez-Juricic 2000).

The first objective of my project was to determine the relative importance of landscape features (such as distance to remnant forest) *versus* local factors (e.g. local vegetation, traffic, feeding stations, cats) in structuring the bird community in residential areas of the city of Edmonton, Alberta, Canada. Second, I examined the effect that landscape and local variables had on the abundance of individual species of resident birds in winter and during the early part of the breeding season in Spring. I evaluated the following predictions:

1. Forest birds, such as Black-capped Chickadee (*Parus atricapillus*) and Red-breasted Nuthatch (*Sitta canadensis*), should be more abundant in neighbourhoods closer to tracts of forested habitat, while non-forest birds e.g. (Black-billed Magpies (*Pica pica*) and Rock Doves) would not show that trend. Black-billed Magpies, however, should be more abundant near agricultural areas.
2. Abundance of forest birds should increase in neighbourhoods with higher local vegetation cover. Conversely, House Sparrows and Rock Doves, which are well adapted to human modified environments, would be more abundant as non-vegetated surfaces increase.
3. Bird feeders or bird boxes should increase bird abundance, while number of predators (domestic cats) and disturbance (e.g. Traffic, Dogs) should reduce it.

METHODS

Study area and design:

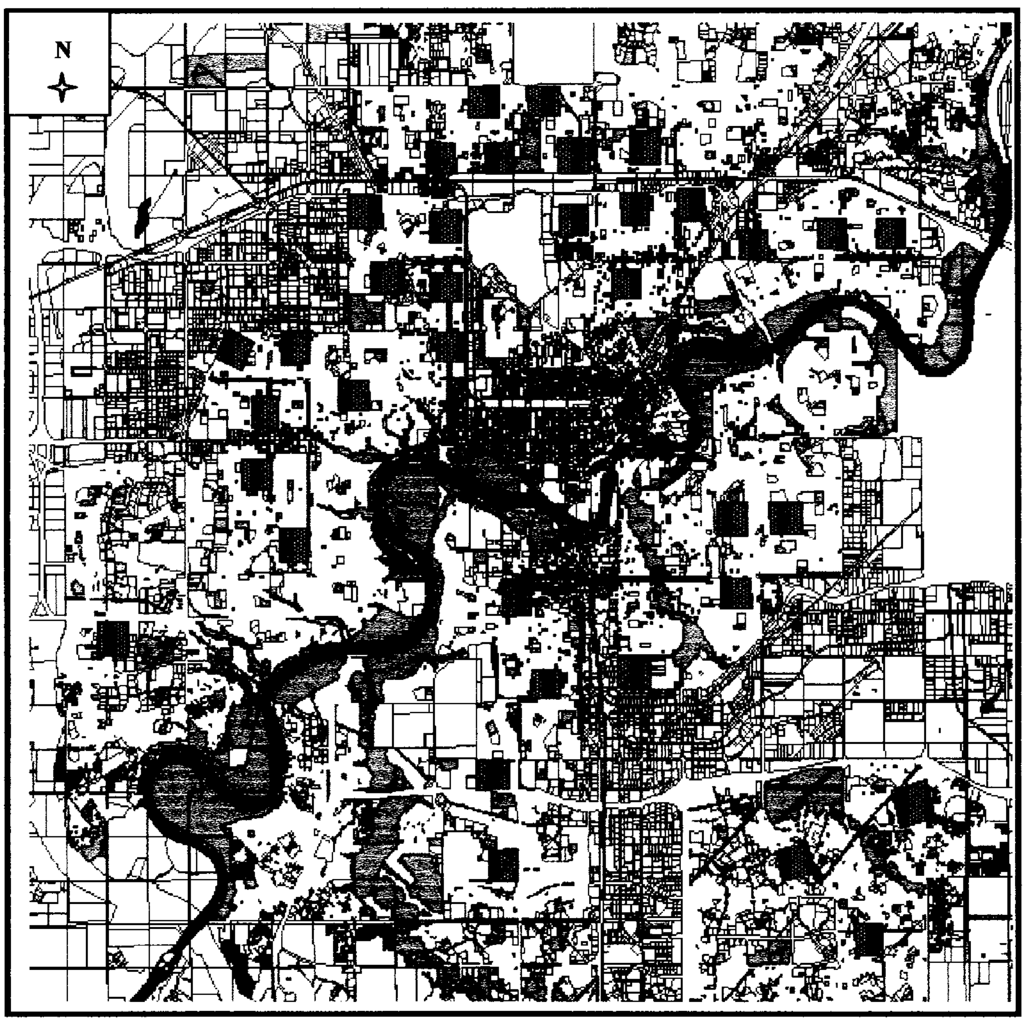
I conducted my research in Edmonton (53°30'N, 113°30' W), Alberta, which is situated in the aspen parkland region of north-central Alberta. The climate is defined by cold, dry winters and warm, wet summers (average temperatures of –10.6 °C and 15.7 °C respectively). Edmonton is the sixth largest metropolitan centre in Canada, covering an area of 70 000ha and holding a population of 666,104 people (City of Edmonton

Annual Report 2003). Edmonton's North Saskatchewan River Valley System is the largest continuous urban park in North America including three major and 19 secondary ravines (Edmonton Parks & Recreation 1992). This 7,400-hectare “green ribbon” still preserves most of its original vegetation dominated by a mixture of white spruce (*Picea glauca*) and trembling aspen (*Populus tremuloides*) with smaller numbers of balsam poplar (*Populus balsamifera*) and birch (*Betula papyrifera*). In the shrub layer the most common species are hazelnut (*Corylus cornuta*), highbush cranberry (*Viburnum trilobum*), saskatoon (*Amelanchier alnifolia*) and rose (*Rosa sp.*).

Residential streets in Edmonton are characterized by sparse vegetation which is mostly introduced. The most common non-native tree species are white elm (*Ulmus americana*), manitoba maple (*Acer negundo*), mountain ash (*Sorbus aucuparia*), green ash (*Fraxinus pennsylvanica*), cherry and plum (*Prunus spp.*) and apple (Malus *spp.*). Other common species are cedar (*Thuja spp.*), caragana (*Caragana arborescens*), cotoneaster (*Cotoneaster acutifolia*) and lilac (*Syringa spp.*).

My study design consisted of a total of 36 square sites of 30ha placed in residential areas throughout Edmonton (Figure 1). Thirty hectares should encompass the territories of at least 6 Black-capped Chickadee, 7 Red-breasted Nuthatch, 3 White-breasted Nuthatch, and/or 6 Downy Woodpecker, based on average breeding territory sizes found in the literature, and taking into account higher density of birds in winter when flocking occurs. They were systematically located to vary the distance to the river valley or ravines and the vegetation between sites. Neighbourhood age varied from 14 to 50 years old. The oldest neighborhoods contained taller and older trees, while newer neighborhoods had more immature vegetation at lower density. A minimum separation of 500m between neighbouring sites was maintained to avoid double counting birds whose home range or territory could overlap two sites and to reduce spatial autocorrelation.

Figure 1. Layout of the study sites in the city of Edmonton. Edmonton landuse 2001 (City of Edmonton, Planning and Development Department). Red squares (30ha) represent the 36 study sites.



Bird Censuses:

I surveyed birds using a 50m wide belt transect (Mikol 1980, Edgar and Kershaw 1994, Jokimaki and Suhonen 1998). A single observer followed a continuous transect along the streets and alleys of each site walking at a speed of approximately 3km h^{-1}. I recorded every bird heard or seen from the transect centre up to the roofline of the closest building, covering approximately 25m on each side. Overflying birds and birds heard or seen outside the 50m strips were not included. The surveys were conducted only when there was no precipitation, temperatures were over –20°C and wind did not exceed 25km h^{-1}.

I sampled my sites twice in winter (7 Dec 2003- 1 March 2004) and once in spring (13 April – 13 June 2004). The average temperatures during my study were -9.0 °C in winter and 7.9°C in spring. These temperatures are close to the interannual averages (-10.6 °C and 8.3 °C respectively), indicating that my results should refect an average year in Edmonton. In winter, surveys were conducted from 9:00 to 14:00, due to the decrease in most species activity after 14:00 (Robbins 1972, Rollfinke and Yahner 1990). For each bird species I chose the maximum number observed over both rounds in each site. However, in spring I only surveyed between dawn and the ensuing three hours, which coincides with the period of higher activity of breeding birds. The order in which the sites were sampled was assigned systematically to avoid confounding the effect of habitat characteristics with the diurnal and seasonal changes in bird activity. Due to high variability in street shape and length across the different neighbourhoods, final abundance of birds was calculated as number of birds divided by transect length and expressed as number of birds per 10km.

Habitat Characteristics:

Landscape measures:

I digitized georeferenced aerial photographs of the City of Edmonton (April 2001 1:20,000, 0.25m pixel resolution) to create a vector data layer of forest cover (ESRI software ArcGIS™ 9.0, 2004). I measured two landscape variables: the minimum distance from the centroid of each site to the nearest forested area in the main river valley or ravine (dist_RiverPark), and the minimum distance from each centroid to the nearest agricultural area (dist_Agriculture).

Local Vegetation and other features:

I surveyed vegetation in a total of six 134m transects in each of my sites. Transects were located systematically (three along streets and three in alleys) spread as far apart as possible to obtain a better representation of the overall vegetation. Every tree and shrub taller than 1m within 25 m on the right side of the transect was identified to genus and height was measured using either a clinometer for tall trees or for shrubs or short trees (less than 6 m) by comparison to the height of the buildings and fences.

Local vegetation data (Appendix II) were used to build four variables: 1) Fruit_Tree: number of fruit bearing trees, including mountain ash, cherry and plum trees and apple trees. These trees might be a food source for birds. 2) Deci_Fencerow: number of deciduous shrubs in hedges (Cotoneaster, Caragana and Lilac). Hedges are the most abundant elements in the shrub layer and can be used as roosts and refuge for some species of songbirds. 3) Conifer: both perennial trees and shrubs are contained under this variable. The dense structure of evergreen species offers protection from weather and predation. 4) TallDeci_Tree: all deciduous trees taller than 6 m, whose size and maturity can provide nest sites and foraging substrates for many birds. In previous studies in Edmonton, Edgar and Kershaw (1994) found a significant relationship between trees taller than 6 m and bird diversity. Furthermore, while doing the bird censuses I mapped locations of additional nesting and food resources such as bird boxes (Box) and feeders (Feeder). The variable feeder included all types of feeding stations (e.g. mixed grain, sunflowers seeds and suet), except for hummingbird feeders.

I also recorded potential predators (domestic cats = Cat) seen within my 50m wide transects and number of dogs (Dog), which can cause disturbances not tolerated by sensitive bird species. I calculated the number of bird boxes, feeders, cats and dogs per 10km.

To quantify the amount of non-vegetated surface and traffic levels I used a Landuse digital layer (Edmonton Land Use 2003, 1:30,000). Non-vegetated surfaces included apartment buildings, industrial and commercial areas and roads. Using ArcGIS version 9.0 (2004), I measured the area without vegetation (Non-Veg500m) and the length of every street and highway contained in a 500m radius from the site centroids. Then, I created an index of traffic within the 500m radius (Traffic_Index500m) as follows. I obtained information on traffic volumes (cars/day) for each road type (Table 1) from the Department of Transportation and Streets (City of Edmonton). I then created a volume index by dividing each volume figure by the volume on the road type with the least traffic (local residential type, Table 1). To determine a traffic volume index for the 500m radius, I multiplied the total length of each road type by the corresponding volume index and summed the products.

Table 1. Correction factors used to estimate the weight of each road type in the local traffic index.

ROAD TYPE	VOLUME INDEX
Highway Arterial A	53.5
Highway Arterial B	43.5
Highway Arterial C	34
Highway Arterial D	25.5
Collector industrial	15
Collector residential	8
Local commercial & industrial	1
Local residential	1

Data Analyses:

I limited my analyses to species found in at least 14% of my sites to avoid transient species and for those with home ranges smaller than 20ha in order to guarantee the independence of the birds seen in adjacent sites. Data for winter and spring were analyzed separately, although I used the same environmental variables and statistical techniques in both cases. None of my variables were highly correlated (all Pearson's $r < 0.60$; Appendix III) and therefore all could be incorporated in subsequent analyses.

Ordination Analyses:

In order to accomplish my objective of determining the relative influence of distance to the River Park vs. local features on community structure, I selected a constrained ordination technique to test directly for the effect of my specific variables on birds (ter Braak 1986). By looking at the axes I can infer the relative importance of local habitat *versus* distance to forested park in explaining the variation in species distribution since explanatory variables that are more highly correlated with the first axes have a higher impact on the overall community.

First, I performed a detrended correspondence analysis (DCA) to decide between linear and non-linear ordination (CANOCO version 4 (ter Braak and Smilauer 1998)). Since the lengths of the gradients in the DCA were consistently short (<1.6SD), implying that most of the response curves were monotonic (Jongman *et al.* 1995), I chose Redundancy analysis (RDA; Rao 1964) as the ordination method. I conducted RDA with the same program. Log-transformation of species data (Log_{10} (X+1)) together with centering and standardization by species were selected in order to make species data more comparable and avoid highly abundant species dominating the ordination (McCune and Grace 2002). A Monte Carlo randomization test (500 random permutations) was simultaneously carried out to examine the significance of the ordination axes obtained (CANOCO 4; ter Braak and Smilauer 1998).

Regression analyses:

To look at influence of my variables on single species, I chose seven resident bird species (Black-capped Chickadee, Red-breasted Nuthatch, Dark-eyed Junco (*Junco hyemalis*), Blue Jay (*Cyanocitta cristata*), Black-billed Magpie, House Sparrow and Rock Dove) to compare the patterns found in winter and spring. I used both forward and backward stepwise generalized linear regression models (GLM; McCullagh and Nelder 1989), with bird abundance (birds/10km) as the dependent variable and local and landscape factors as independent variables.

I applied GLMs assuming a Poisson distribution (Hoffman 2004, McCullagh and Nelder 1989) for all my species, except Rock Doves and Dark-eyed Juncos. For the two latter species I used presence/absence data in a binomial logistic regression model. For models that were overdispersed, I applied a quasi-likelihood function (Crawley 1993);

which allows one to create the regression model without specifying the error distribution of the response variable (McCullagh and Nelder 1989). All the GLMs were carried out using S-PLUS version 6.2 (2003).

Although local vegetation features and distance to the River Valley Park were the main variables I wanted to test, I decided to examine also the effect of the variables Feeder, Cat, Dog and Traffic_Index500m for all the species. In addition, in some cases I included other variables which might be of special interest for certain species. I incorporated the number of bird boxes in the regressions of cavity nesters, the dist_Agriculture for the Magpies and the Non-Veg500m for the exotic species, such as Rock Dove and House Sparrows.

RESULTS

Bird Occurrence:

During my bird surveys in winter (approximately 140 hours covering 381 km of residential streets and alleys) and in spring (approximately 70 hours and 190 km), I observed a total of 21 species in winter and 38 in spring (Appendix I). Approximately 40% of the species were found in less than 5 sites and therefore were omitted from my analyses. Other species with large home ranges, such as European Starlings (*Sturnus vulgaris*), Ringed-billed Gulls (*Larus delawarensis*), Northern Flickers (*Colaptes auratus*) and large corvids (*Corvus brachyrhynchos* and *Corvus corax*), were also omitted. Among these large species, Merlins (*Falco columbarius*) were the only birds of prey I encountered during my surveys. Eighty percent of the times they were found in neighbourhoods within 1500 m from the River Valley Park.

The total number of species analyzed was 10 in winter and 16 in spring (Table 2). The most abundant species in both seasons was the House Sparrow (Table 2), which occurred in all sites and was four times more abundant than the other species. Other common species were Black-capped Chickadee, Red-breasted Nuthatch, Blue Jay, Black-billed Magpie, and American Robin (*Turdus migratorius*) in spring and Redpolls (*Carduelis sp.*) in winter (Table 2). Although the Downy Woodpecker (*Picoides pubescens*) is a resident species, I only found it during the winter survey (approximately in 70% of my study sites) (Table 2 and Appendix I).

Table 2. List of species used in the analyses (RDA and GLMs). This table includes the number of sites in which they were detected (a total of 36 were sampled) as well as the average bird abundance (birds/10km) and density (birds/ha) on occupied sites. The only species without Species Code were Common Redpoll (*Carduelis flammea)* and Hoary Redpoll (*Carduelis hornemanni*), which were both grouped under the category REDPOLL due to the difficulty of distinguishing them. Refer to Appendix I for scientific names.

		Winter			Spring		
		Number of Sites	Bird abundance	Bird Density	Number of Sites	Bird abundance	Bird Density
AMRO	American Robin				36	39.6	0.79
BBMA	Black-billed Magpie	36	20.6	0.41	35	15.1	0.30
BCCH	Black-capped Chickadee	36	30.6	0.61	35	12.4	0.25
BLJA	Blue Jay	36	6.5	0.13	34	7	0.14
CCSP	Clay-coloured Sparrow				16	6.5	0.13
CEWA	Cedar Waxwing				5	13.6	0.27
CHSP	Chipping Sparrow				23	62.5	1.25
DEJU	Dark-eyed Junco	28	11.5	0.23	9	7.3	0.15
DOWO	Downy Woodpecker	26	2.5	0.05			
HOSP	House Sparrow	36	185.8	3.72	36	278.8	5.58
HOWR	House Wren				6	6	0.12
PUFI	Purple Finch				6	4.2	0.08
RBNU	Red-breasted Nuthatch	34	10.1	0.20	33	5.2	0.10
REDPOLL	Redpoll	35	21.8	0.44			
RODO	Rock Dove	20	18.1	0.36	24	20.8	0.42
SOSP	Song Sparrow				7	4.6	0.09
WBNU	White-breasted Nuthatch	22	2.8	0.06			
WCSP	White-crowned Sparrow				8	8.5	0.17
WTSP	White-throated Sparrow				18	6.3	0.13

Relationship between the bird community and environmental variables:

Three axes of the RDA explained 34% and 28% of the variation in the data in winter and spring, respectively (Table 3). Figures 2 and 3 contain joint plots of bird species and environmental variables for winter and spring seasons respectively: I only included the first two axes to facilitate interpretation. A level of significance smaller than 0.05 (winter and spring), indicates that these ordinations offer a reasonable explanation of species-habitat relationships (Monte Carlo randomization test; CANOCO 1998). Since the first two axes do not explain much variation, it is difficult to make inferences about habitat associations of individual species using the ordination plots. However, the main goal of the RDA is to reveal which environmental variables (landscape *versus* local feature) are more important to explain the structure of the overall community. The variables with higher correlation coefficients with the ordination axes (Table 4) have a higher impact in the overall community.

None of the environmental variables had high correlations with the ordination axes; however, in both seasons the main two axes were consistently more correlated with local variables than with landscape features (Table 4, Figures 2 and 3). In winter, local vegetation cover characteristics such as number of conifers or deciduous trees taller than 6 m had significant correlations with the first two axes, while distances to parks or agricultural areas had lower and non-significant correlations. Conifers or deciduous tall trees were negatively correlated with the main axis (Figure 2), driving most of the bird species in the ordination to the negative portion of axis I. Other local variables (cats, dogs, bird feeders or bird boxes) were not significantly correlated with any of the two first axes (Table 4), indicating that their influence on the overall winter community was insignificant. In spring, local vegetation again had a higher effect on the bird community (first two axes) compared with landscape structure and bird boxes and cats became significant (Figure 3). The number of bird boxes was the dominant variable of the spring RDA. Since bird boxes were positively related to axis I and numbers of conifers and tall deciduous trees had a negative association to axis II, most of the spring bird species appear to be located toward the right end of axis I and lower portion of the second axis.

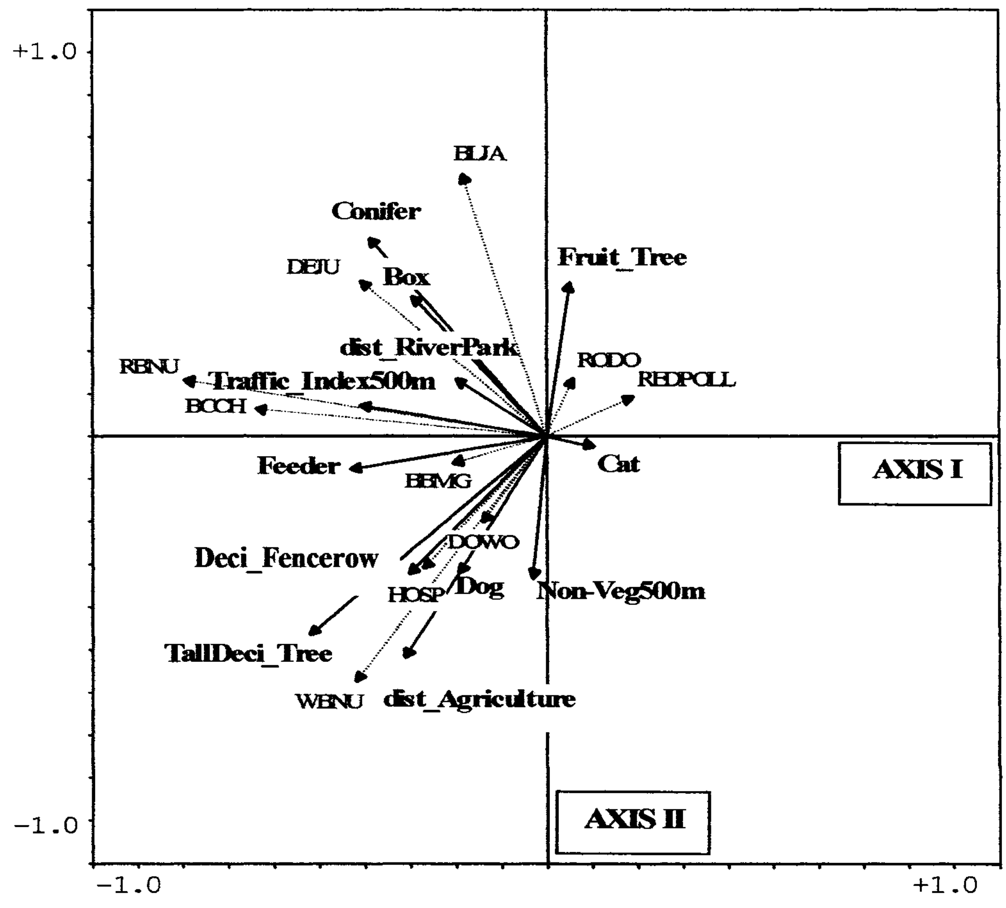


Figure 2. Ordination diagram (RDA) of ten winter bird species to investigate the relative importance of distance to river valley parkland (dist_RiverPark) and local habitat characteristics in defining bird community structure. Except for Redpolls, species are represented by their four-letter codes (Table 2) and variables represented by lower-case letters. Sites were omitted to reduce complexity.

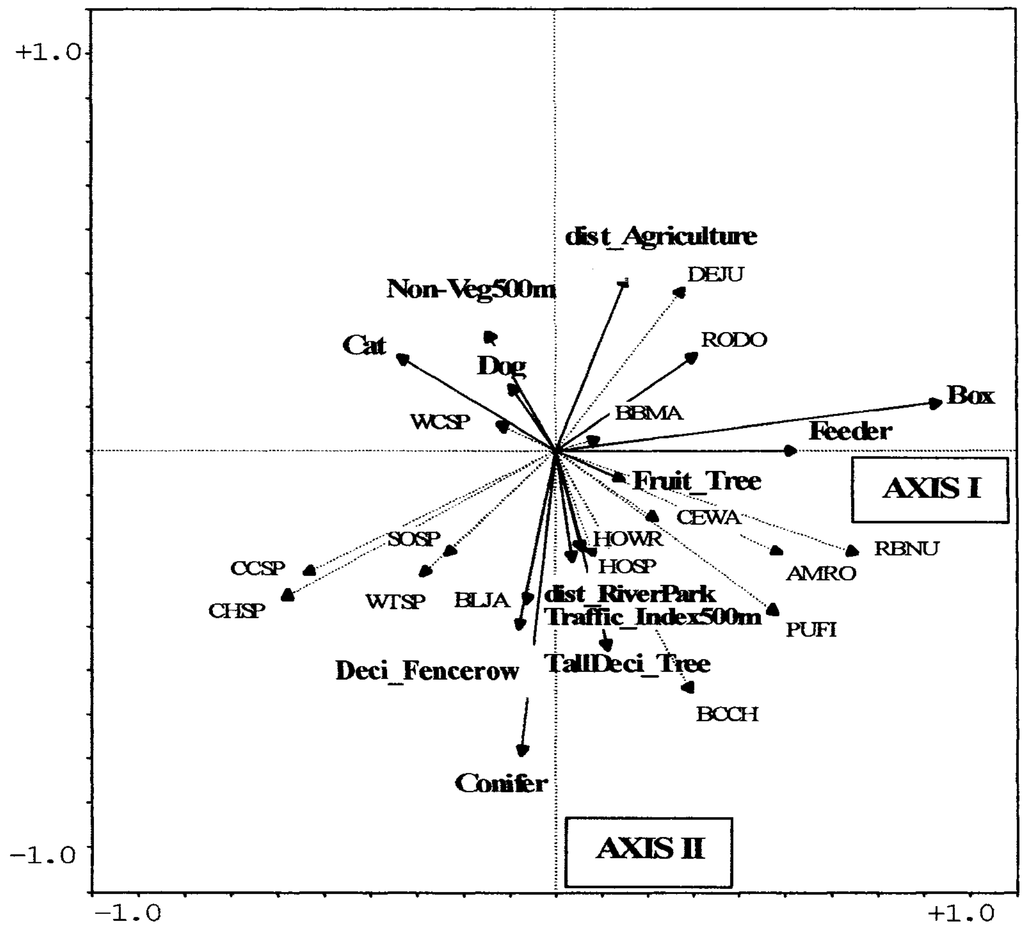


Figure 3. Ordination diagram (RDA) of 16 spring bird species to investigate the relative importance of distance to river valley parkland (dist_RiverPark) and local habitat characteristics in defining bird community structure. Except for Redpolls, species are represented by their four-letter codes (Table 2) and variables represented by lower-case letters. Sites were omitted to reduce complexity

Table 3. Variance of the species data explained by the first three RDA axes (winter and spring).

Variance	Axis I	Axis II	Axis III	TOTAL
Winter	16%	10%	8%	**34%**
Spring	13%	8%	7%	**28%**

Table 4. Correlation coefficients between habitat variables and main ordination axes (winter and spring). Significant correlations represented by an asterisk ($p \leq 0.05$). Refer to Appendix IV to see the mean and variation of the explanatory variables.

RDA Axes	Winter			Spring		
	Axis I	Axis II	Axis III	Axis I	Axis II	Axis III
Minimum distance to river valley or ravines (dist_RiverPark)	**-0.16***	0.10	0.14	0.05	**-0.17***	**0.15***
Minimum distance to agricultural areas (dist_Agriculture)	-0.25	-0.40	-0.09	0.13	0.29	0.38
Number of Fruit bearing trees (Fruit_Tree)	0.04	**0.27***	0.33	0.12	-0.05	-0.12
Number of deciduous shrubs usually in hedges (Deci_Fencerow)	-0.22	-0.24	0.11	**-0.07***	-0.30	0.15
Number of evergreen trees and shrubs (Conifer)	**-0.31***	**0.35***	0.27	-0.06	**-0.51***	**-0.50***
Number of deciduous trees taller than 6 meters (TallDeci_Tree)	**-0.42***	-0.36	0.07	**0.08***	**-0.32***	**0.51***
Number of nest boxes (Box)	-0.24	0.25	-0.21	**0.70***	0.08	-0.29
Number of feeding stations (Feeder)	-0.35	-0.06	-0.13	0.44	0.00	-0.07
Number of outdoor cats (Cat)	0.08	-0.02	**-0.38***	**-0.28***	0.16	**0.26***
Number of dogs (Dog)	-0.16	**-0.25***	**0.28***	-0.08	0.11	**0.03***
Non-vegetated area within a 500m radius (Non-Veg500m)	-0.03	-0.25	**-0.03***	-0.13	0.20	0.39
Index of traffic within 500m radius (Traffic_Index500m)	**-0.33***	0.06	**-0.05***	0.03	-0.18	**0.14***

Effect of habitat variables on individual resident species:

In the regression analyses for the seven resident species, local features also proved to have a much stronger influence on bird abundance than landscape variables. The number of conifer trees and shrubs had a positive influence on the abundance of forest birds, especially in winter (Table 5, Figure 4). The importance of conifers for Red-breasted Nuthatches in winter was replaced in spring by the availability of bird boxes and trees bearing fruits. Dark-eyed Juncos also shifted from being associated with neighbourhoods with high conifer abundance in winter to avoidance of sites with tall deciduous trees in spring (Table 5).

The numbers of Black-capped Chickadee in spring and Dark-eyed Junco in both seasons were positively associated with feeders, and Blue Jay abundance was positively related to fruit trees in winter. During winter Blue Jays were also more abundant the farther they were from the river park. Cats, Dogs, Traffic and abundance of deciduous shrubs (Deci_Fencerow) did not have significant effects for any of the species (Table 5). No variables entered models for Magpies or Rock Doves, and House Sparrows only showed a positive relationship to deciduous trees taller than 6 m (TallDeci_Tree) in both seasons (Table 5).

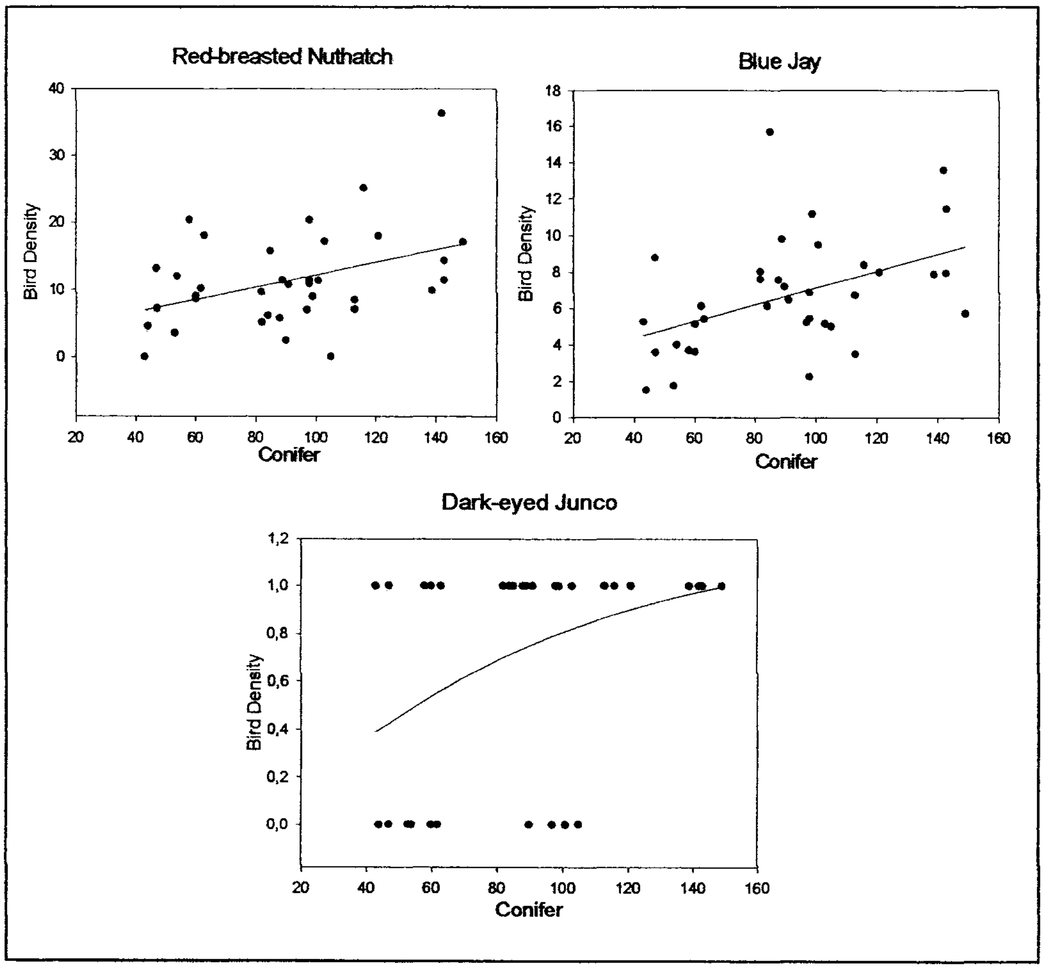


Figure 4. Effect of coniferous trees and shrubs on the winter distribution of three resident species.

Table 5. Results of the generalized linear models (GLM) for the seven resident bird species examined (winter=W, spring=S). Significant environmental variables are expressed with their coefficients and percentage of deviance explained (*= p <0.05, **= p <0.01, ***=p<0.001 and ns = not significant). Refer to Appendix IV to see the Mean and variation of the variables.

	Black-capped Chickadee		Red-breasted Nuthatch		Dark-eyed Junco		Blue Jay		Black-billed Magpie		House Sparrow		Rock Dove	
	W	S	W	S	W	S	W	S	W	S	W	S	W	S
dist_RiverPark	ns	ns	ns	ns	ns	ns	0.0001* 12.2%	ns	ns	ns	ns	ns	ns	ns
dist_Agriculture									ns	ns				
Fruit_Tree	ns	ns	ns	0.01* 8.0%	ns	ns	0.01* 11.1%	ns	ns	ns	ns	ns	ns	ns
Deci_Fencerow	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Conifer	ns	0.01*** 32.4%	0.01* 15.4%	ns	0.03* 14.6%	ns	0.01** 20.6%	0.01* 10.5%	ns	ns	ns	ns	ns	ns
TallDeci_Tree	ns	ns	ns	ns	ns	-0.08** 18.8%	ns	ns	ns	ns	0.01* 13.9%	0.01* 16.7%	ns	ns
Box	ns	ns	ns	0.02*** 27.3%							ns	ns		
Feeder	ns	0.01* 9.7%	ns	ns	0.05* 10.6%	0.05* 12.2%	ns	ns	ns	ns	ns	ns	ns	ns
Cat	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Dog	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns
Non-Veg500m											ns	ns	ns	ns
Traffic_Index500m	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns

DISCUSSION

I used a multi-scale approach to assess the relative value of local vs. landscape characteristics in structuring the bird community and to investigate the potential influence of the River Valley Park on bird populations in residential areas. Similar to Clergeau *et al.* (2001), in both seasons, birds consistently had a much greater association with local habitat features than with landscape structure. In my study, at the local level the main predictors were vegetation cover (i.e. conifers and deciduous trees taller than 6 m) and food resources, such as feeders and fruit trees. The relevance of these variables changed with the season of the year.

Melles *et al.* (2003) also concluded that "urban-adapted" species, such as Black-capped Chickadees and Violet-green Swallows (*Tachycineta thalassina*), responded to local-level habitat, while more sensitive species (e.g. Winter Wrens (*Troglodytes troglodytes*)) and shrub-nesting species were also associated with landscape features because they appeared more frequently within or near large parks. It is possible that when I selected the species occupying more than 14% of the sites, I was also choosing the "urban-adapted" species, which can use the abundant vegetation and food resources found in streets of Edmonton as an alternative habitat (Fernandez-Juricic 2000). Perhaps, some of the species I did not include in my analyses because of their rarity could have been significantly influenced by the distance to the river valley forest. Other bird species, such as Downy Woodpeckers, depend on mature trees and snags found in forested areas to excavate their nests (Conner *et al.* 1976, Harestad and Keisker 1989). This could explain why Downy Woodpeckers were only found in my residential sites during the winter. Non-significant effects of the distance to Agricultural areas or Forested Park could be also due to a scale issue. Munyenyembe *et al.* 1989 and Melles *et al.* 2003 showed that birds were only affected by wooded areas within a small radius (shorter than 1000m). The result in these two studies could represent a case of habitat complementation (Dunning *et al.* 1992), where species roosting and nesting in forest patches take advantage of resources found in residential areas (such as bird feeders).

Since urban environments have many confounding factors that increase the level of noise in the data, lack of statistical power could be another reason why I did not obtain any significant positive effect of distance to the river valley forest. However, correlations between species and environmental variables in both seasons (Appendix V) show that distance to River Park was not correlated to any of the species' abundances (Pearson's $r \leq 0.23$) and thus low statistical power would not be the cause of the non-significant effects of this variable.

The abundance of Black-billed Magpies and Rock dove was not correlated with any of the habitat variables. Magpies were present in practically all sites. This omnivorous species is usually associated with open areas where it forages on the ground (Linsdale 1946, Trost 1999). The foraging surface offered by yard lawns in all neighbourhoods together with opportunistic feeding of this species, could explain why they did not respond specifically to any of the variables included in this study. Rock Doves are usually associated with the most urbanized areas, such as city centres and industrial areas (Lancaster and Rees 1979). Rottenborn (1999) showed that this species increased with the number of bridges and as the distance to buildings decreased. Some variables I did not consider (such as distance to bridges, large buildings, downtown or industrial areas) could be responsible for the distribution of this species.

House Sparrows were only associated with increasing numbers of tall deciduous trees in both seasons. They are usually restricted to human environments and avoid woodlands (Lancaster and Rees 1979, Lowther and Cink 1992). Some authors have found that this exotic species increases with the non-vegetated surface (Campbell and Dagg 1976 and Melles *et al.* 2003). I did not find a significant effect of non-vegetated areas on House Sparrows; probably because the range of habitats in my sites was lower than in those studies (i.e. Forested parks and downtown areas were not included in my sites). Tall deciduous trees were correlated with total number of trees and shrubs (Pearson's $r = 0.67$) on residential streets. This could imply that within the residential areas, House Sparrows take advantage of the more vegetated neighbourhoods for roosting, foraging and nesting (Lenz 1990).

Native forest birds increased with increasing numbers of conifers in both seasons. These species likely use conifers for thermal protection for roosting and for foraging. In the spring, however, the importance of conifers decreased for some species (Dark-eyed Junco and Red-breasted Nuthatch). Red-breasted Nuthatch abundance increased with the abundance of bird boxes, suggesting that they use the bird boxes to nest. Dunn *et al.* (1975) reported that Red-breasted Nuthatches bred in nest boxes in Ontario. In spring, Dark-eyed Juncos were negatively related to deciduous trees taller than 6 m, possibly because they move to more open areas to nest (Martin 1998).

Exotic fruit trees (e.g. apple and plum trees) and feeding stations are an easily accessible source of food for birds in cities. Blue Jays and Red-breasted Nuthatches responded positively to the number of fruit trees in winter and spring respectively. Apple and plum trees maintain some of their fruit through the winter months (Bovey 1988), providing Blue Jays with one of their main food items (Tarvin and Woolfenden 1999). Red-breasted Nuthatches can occasionally consume fruit (Bent 1964, Ghalambor and Martin 1999) and are also attracted to insect pests found in fruit trees (Canadian Wildlife Service 1978). This could account for the relationship found between Red-breasted Nuthatches and fruit trees in spring. Black-capped Chickadee and Dark-eyed Juncos were at higher abundance in areas with more feeding stations. These omnivorous species might take advantages of seeds (especially sunflower seeds) and suet provided in the feeding stations (Bovey 1988) and they are two of the most common species at feeders (Horn *et al.* 2003).

Contrary to my prediction, Blue Jay abundance in winter decreased the closer they were to the forested parks. The fact that this pattern only appeared in winter might be an indication that sites placed farther from the forested park contain some characteristics necessary for Blue Jays' winter diet that I did not consider. Hard mast (such as acorns and other nuts) can compose up to 67% of the Blue Jay's winter diet in some locations (Tarvin and Woolfenden 1999). However, oak trees are introduced and rare in Edmonton and their prevalence did not increase with distance to the river park (Pearson's $r = -0.2$). Since blue jays are opportunistic feeders, they can eat carrion and human food waste (Lamore 1958, Goodwin 1976, Madge and Burn 1994), and they use these sources more frequently in winter (Lamore 1958). The reason why Blue Jays are more abundant in sites farther from the river can be that those neighbourhoods might be closer to industrial and commercial areas, where there is a higher accumulation of garbage.

Many authors have suggested that the presence of domestic cats in cities might decrease the abundance of birds (Emlen 1974, Soulé *et al.* 1988, Coleman *et al.* 1997). However, only a few (Crooks & Soule 1999, Rottenborn 1999) have tested for a relationship between cat density and bird abundance. Crooks and Soule (1999) found that the abundance of mesopredators (foxes, raccoons, skunks and domestic cats) increased in habitat fragments with fewer coyotes and consequently the bird diversity decreased. Contrarily, Rottenborn (1999) could not demonstrate the effect of cats on any of the 48 riparian bird species analyzed. We also found no relationship between cat and bird abundance, even though cat abundance varied greatly across sites (Appendix IV).

Several studies have concluded that songbirds comprise only a small percentage of the diet of well-fed urban cats (Eberhard 1954, Liberg 1984, Barratt 1998, Kays *et al.* 2004). Besides, domestic cats prey more often upon the more abundant non-native species (Chace and Walsh 2006). During my surveys I found an average of 0.19 cats/km of transect which would correspond to 0.003 cats/household. Studies on domestic cat predation by Barrat (1998), Lepczyk *et al.* (2003) and Kays and DeWan (2004) have reported a density of outdoor cats of 0.48, 1.94 and 0.28 cats/household respectively. Although differences in the method of survey make these densities not entirely comparable, it suggests that density of outdoor cats in Edmonton might be too low to have a significant effect on birds. The cold temperatures reached in Edmonton winters might also be one of the causes of the low numbers of outdoor cats.

Finally, I did not detect any negative effects of disturbance factors such as traffic levels and dogs on birds. Although dogs do not usually depredate birds (Lafferty 2001, Jokimaki *et al.* 2005), they can chase them, reducing feeding time and subsequent fitness

(Lafferty 2001, Randler 2003). Most of the dogs in my study area were leashed or enclosed in backyards, reducing their potential impact on birds.

Contrary to many authors (Reijnen and Foppen 1995, Reijnen *et al.* 1996, Fernandez-Juricic 2000, Forman *et al.* 2002), I did not find any negative association between road traffic and bird abundance. Over 81% of the streets around my sites were local and collector roads. According to data from the Department of Transportation and Streets of City of Edmonton, those road types have a traffic volume usually under 10,000 cars/day, which might not be heavy enough to influence the abundance of the species analyzed. This agrees with Forman *et al.* 2002 who concluded that a volume lower than 8,000 cars/day had no significant effect and between 8,000 and 15,000 cars/day reduced breeding but did not affect the presence of birds. Fitzpatrick and Bouchez 1998 suggested that birds exposed to regular disturbances can habituate to them. This could be the case of the species living in urban environments.

Conservation implications:

Conservation efforts have traditionally concentrated on protecting natural ecosystems, overlooking the biodiversity found in urbanized areas (Jules 1997, Vandermeer 1997). Yet, as cities expand, an increasing proportion of bird populations will be forced to adapt to urban conditions in order to survive. City managers should integrate the results of this and other similar studies into future planning, if urban biodiversity is to be preserved.

My results suggest that each species responded to different environmental cues and scales, thus, increasing habitat heterogeneity of streets and green spaces around Edmonton could favour bird species richness. Trees such as conifers and fruit trees could be planted in all urban parks, golf courses and along sidewalks. These tree species are beneficial for resident birds, especially for native forest birds which depend more on this type of vegetation than exotic species such as Rock Doves and House Sparrows. Encouraging home owners to supply feeders and nest boxes could also increase abundance of several species. Negative effects of feeders, such as higher rate of disease transmission, could be reduced by regular cleaning (Brittingham and Temple 1988) and feeders could attract a higher diversity of species by varying feeder design and food provided (Jokimaki and Suhonen 1998). Jackson and Tate (1974) showed that House Sparrows occupied multiple-nest boxes more frequently than single bird boxes, and thus, restricting this type of boxes could discourage gregarious exotic species from using them.

A wildlife inventory conducted by Spencer (1976) in four ravines of the North Saskatchewan River Valley reported a total of 33 species in winter and 62 in the breeding season. In the residential areas, I only encountered a total of 21 and 38 species in winter and summer respectively. This suggests that, although I could not demonstrate any positive effect of forested areas on bird species inhabiting residential areas, many other species might be restricted to more "natural" habitats and dense vegetation found in the river park where they can survive and breed. Hence, protection of the forested river valley and ravine will maintain higher biodiversity within the city.

Future research:

In order to reveal underlying source-sink dynamics occurring in the city of Edmonton further research could compare bird abundance and breeding success in wooded streets *versus* the River Valley Park. Banding. Radiotracking fledglings would also provide information about dispersal from forested parks into residential areas.

Additional studies could examine species' diets in urban settings and how they differ from those in natural habitats. Apart from studying the importance of feeders, these studies could assess the relative contribution of native *versus* exotic fruit and berry producing plants to the urban bird's diet. More information is also needed about the effect of urbanization on species home range and territory sizes. While lower plant cover can lead to larger home ranges in order to satisfy nutritional needs, additional feeding supplied by humans in seed and suet feeders might have the opposite effect. Finally, it would be interesting to explore processes such as competition at feeders and bird boxes, as well as, investigate patterns of movement for different species across the urban landscape.

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APPENDICES

APPENDIX I: Species observed during winter and spring bird surveys. Statistical analyses were only applied to species in bold.

Common	Scientific Name	Season (W= winter, S=spring)
American Crow	*Corvus brachyrhynchos*	W,S
American Goldfinch	*Carduelis tristis*	S
American Robin	***Turdus migratorius***	**S**
Black-billed Magpie	***Pica pica***	**W,S**
Black-capped Chickadee	***Parus atricapillus***	**W,S**
Blue Jay	***Cyanocitta cristata***	**W,S**
Bohemian Waxwing	*Bombycilla garrulus*	W,S
Brewer's Blackbird	*Euphagus cyanocephalus*	S
Brown Creeper	*Certhia americana*	W
Cedar Waxwing	***Bombycilla cedrorum***	**W,S**
Chipping Sparrow	***Spizella passerina***	**S**
Clay-coloured Sparrow	***Spizella pallida***	**S**
Common Grackle	*Quiscalus quiscula*	S
Common Raven	*Corvus corax*	W,S
Dark-eyed Junco	***Junco hyemalis***	**W,S**
Downy Woodpecker	***Picoides pubescens***	**W**
European Starling	*Sturnus vulgaris*	W,S
Golden-crowned Kinglet	*Regulus satrapa*	S
House Sparrow	***Passer domesticus***	**W,S**
House Wren	***Troglodytes aedon***	**S**
Merlin	*Falco columbarius*	W,S
Northern Flicker	*Colaptes auratus*	W,S
Northern Shrike	*Lanius excubitor*	W
Pine Siskin	*Carduelis pinus*	W,S
Purple Finch	***Carpodacus purpureus***	**S**
Red-breasted Nuthatch	***Sitta canadensis***	**W,S**
Red-eyed Vireo	*Vireo olivaceus*	S
Redpoll	***Carduelis sp.***	**W**
Ring-billed Gull	*Larus delawarensis*	S
Rock Dove	***Columba livia***	**W,S**
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	S
Ruby-crowned Kinglet	*Regulus calendula*	S
Rusty Blackbird	*Euphagus carolinus*	S
Savannah Sparrow	*Passerculus sandwichensis*	S
Song Sparrow	***Melospiza melodia***	**S**
Swainson's Thrush	*Catharus ustalutus*	S
Tree Swallow	*Tachycineta bicolor*	S
White-breasted Nuthatch	***Sitta carolinensis***	**W,S**
White-crowned Sparrow	***Zonotrichia leucophrys***	**S**
White-throated Sparrow	***Zonotrichia albicollis***	**S**
White-winged Crossbill	*Loxia leucoptera*	W
Yellow Warbler	*Dendroica petechia*	S
Yellow-bellied Sapsucker	*Sphyrapicus varius*	S

APPENDIX II: Tree and shrub species found in vegetation transects. Total represents the number of individuals in the 72 ha surveyed, while the other columns represent density (individuals/ha) in a site basis.

Common names	Scientific names	Total	Mean	Min	Max	C.V
Cotoneaster	*Cotoneaster acutifolia*	2413	33.5	4	87	0.6
Spruce	*Picea spp*	1476	20.5	6	36.5	0.4
Cedar	*Thuja spp*	1247	17.3	5	56	0.6
Manitoba Maple	*Acer negundo*	1247	17.3	3	46	0.6
Lilac	*Syringa spp*	1159	16.1	6	37	0.5
Raspberry and Blackberry	*Rubus spp*	898	12.5	0	54	0.8
Cherry and Plum	*Prunus sp*	879	12.2	3	29.5	0.4
Green ash	*Fraxinus pennsylvanica*	804	11.2	0	35	0.8
Apple	*Malus spp*	761	10.6	4.5	20	0.3
Elm	*Ulmus spp*	574	8.0	0	24.5	0.7
Caragana	*Caragana arborescens*	479	6.7	0	53	1.7
Birch	*Betula spp*	448	6.2	1	24.5	0.8
Rose	*Rosa spp*	411	5.7	1.5	11	0.4
Mountain ash	*Sorbus aucuparia*	312	4.3	0	8.5	0.5
Pine	*Pinus spp*	292	4.1	0	10.5	0.7
Juniper	*Juniperus spp*	219	3.0	0	13	1.1
Currant and Gooseberry	*Ribes spp*	206	2.9	0	33	2.1
Poplar	*Populus spp*	125	1.7	0	8.5	1.3
Elder	*Sambucus spp*	122	1.7	0	18	1.8
Cinquefoil	*Potentilla spp*	109	1.5	0	6.5	1.2
Dogwood	*Cornus spp*	86	1.2	0	3.5	0.9
Spirea	*Spiraea spp*	80	1.1	0	3.5	0.9
Willow	*Salix spp*	72	1.0	0	3.5	1.0
Honeysuckle	*Lonicera spp*	68	0.9	0	4.5	0.9
Cranberry	*Viburnum spp*	58	0.8	0	2.5	0.9
Mockorange	*Philadelphus spp*	55	0.8	0	3	1.0
Serviceberry	*Amelanchier spp*	53	0.7	0	4.5	1.5
Sumac	*Rhus spp*	48	0.7	0	5	2.3
Oak	*Quercus spp*	27	0.4	0	1.5	1.2
Ninebark	*Physocarpus spp*	26	0.4	0	3	1.9
Oleaster	*Elaeagnus spp*	24	0.3	0	2	1.6
Linden	*Tilia spp*	16	0.2	0	2	1.8
Fir	*Abies spp*	13	0.2	0	1.5	2.2
Larch	*Larix spp*	12	0.2	0	1.5	2.4
Hawthorne	*Crataegus spp*	10	0.1	0	1	2.0
Barberry	*Berberis spp*	8	0.1	0	1.5	2.9
Ohio buckeye	*Aesculus glabra*	8	0.1	0	2	3.4
Buckthorn	*Rhamnus spp*	5	0.1	0	1	3.5
Hazelnut	*Corylus avellana*	2	0.0	0	0.5	4.2
Horse chestnut	*Aesculus hippocastanum*	2	0.0	0	0.5	4.2
Prinsepia	*Prinsepia spp*	2	0.0	0	0.5	4.2
Hemlock	*Tsuga spp*	1	0.0	0	0.5	6.0
Locust	*Robinia spp*	1	0.0	0	0.5	6.0

APPENDIX III: Matrix of correlation coefficients among environmental variables (Pearson's r). Variables in bold were included in the analyses. All correlations are significant (α = 0.05).

	Neighbourhood Age	Total Trees and Shrubs	Mean Height	Height Diversity	**Fruit_Tree**	**Deci_Fencerow**	**Conifer**	**TallDeci_Tree**	Birch
Neighbourhood Age	1								
Total Trees and Shrubs	0.27	1							
Mean Height	0.41	0.13	1						
Height Diversity	0.32	0.09	0.93	1					
Fruit_Tree	-0.30	0.34	-0.31	-0.29	1				
Deci_Fencerow	0.26	0.77	0.10	-0.02	**0.13**	1			
Conifer	-0.02	0.58	0.05	0.05	**0.09**	**0.19**	1		
TallDeci_Tree	0.40	0.67	0.71	0.66	**0.05**	**0.56**	**0.18**	1	
Birch	-0.04	0.33	-0.23	-0.28	0.17	0.01	0.59	-0.07	1
VegSpp Diversity	-0.31	-0.15	-0.16	-0.05	0.29	-0.47	0.07	-0.14	0.22
VegSpp Richness	-0.26	0.39	-0.37	-0.30	0.35	0.23	0.32	0.04	0.33
Non-Veg500m	0.28	-0.08	0.34	0.31	**-0.23**	**0.08**	**-0.37**	**0.24**	-0.38
Feeder	0.24	0.12	0.35	0.27	**-0.12**	**0.08**	**0.15**	**0.10**	0.00
Cat	0.02	-0.41	-0.05	0.07	**-0.27**	**-0.39**	**-0.32**	**-0.22**	-0.34
Box	0.29	-0.03	0.06	0.02	**-0.02**	**-0.14**	**0.05**	**-0.15**	0.09
Dog	0.09	-0.20	0.12	0.12	**0.09**	**-0.25**	**-0.13**	**-0.06**	-0.19
Traffic_Index500m	0.15	0.11	0.09	0.02	**0.02**	**0.18**	**0.09**	**0.03**	0.31
dist_RiverPark	0.16	-0.12	-0.25	-0.27	**-0.02**	**-0.02**	**-0.23**	**-0.28**	-0.09
dist_Agriculture	0.46	0.05	0.38	0.32	**0.03**	**0.11**	**-0.31**	**0.38**	-0.40

	VegSpp Diversity	VegSpp Richness	**Non-Veg500m**	**Feeder**	**Cat**	**Box**	**Dog**	**Traffic_ Index500m**	**dist_ RiverPark**	**dist_ Agriculture**
VegSpp Diversity	1									
VegSpp Richness	0.44	1								
Non-Veg500m	-0.10	-0.16	1							
Feeder	-0.29	-0.26	**-0.04**	1						
Cat	0.03	-0.22	**0.06**	**-0.14**	1					
Box	-0.20	-0.32	**-0.15**	**0.58**	**-0.07**	1				
Dog	-0.01	-0.31	**0.02**	**0.01**	**0.36**	**-0.05**	1			
Traffic_Index500m	-0.13	0.04	**0.40**	**0.13**	**-0.12**	**-0.06**	**0.15**	1		
dist_RiverPark	-0.08	-0.03	**-0.08**	**-0.01**	**0.11**	**-0.06**	**0.04**	**0.03**	1	
dist_Agriculture	-0.14	-0.46	**0.20**	**0.05**	**0.15**	**0.07**	**0.34**	**-0.21**	**-0.13**	1

APPENDIX IV: Mean and variation of the explanatory variables included on the analyses.

N = 36	Mean	Min	Max	C. V.
dist_RiverPark (m)	1789.25	633.0	4912.9	0.65
dist_Agriculture (m)	2503.09	441.7	5340.1	0.44
Fruit_Tree (Number of trees in 804m)	54.39	29	106	0.28
Deci_Fencerow (Number of shrubs in 804m)	112.53	44	223	0.41
Conifer (Number of trees & shrubs in 804m)	90.56	43	149	0.34
TallDeci_Tree (Number of trees in 804m)	66.47	20	147	0.39
Box (Boxes/10km)	48.20	17.1	110.2	0.48
Feeder (Feeders/10km)	47.94	16.6	149.1	0.60
Cat (Cats/10km)	1.91	0.0	9.3	1.12
Dog (Dogs/10km)	24.75	9.0	48.0	0.41
Non-Veg500m (m^2)	363069.28	255130.9	463734.0	0.15
Traffic_Index500m (No units)	91468.16	37117.5	239797.7	0.49

APPENDIX V: Correlation matrix (Pearson's r) among environmental variables and individual species. A) Winter and B) Spring .

A)

Winter	**Black-capped Chickadee**	**Red-breasted Nuthatch**	**Dark-eyed Junco**	**Blue Jay**	**Black-billed Magpie**	**House Sparrow**	**Rock Dove**
dist_RiverPark	0.05	0.07	-0.06	0.23	0.14	0.01	-0.16
dist_Agriculture	0.05	0.03	-0.11	-0.09	0.06	0.13	0.03
Fruit_Tree	-0.18	0.02	0.03	0.35	0.02	0.19	-0.15
Deci_Fencerow	-0.13	0.09	0.07	0.10	-0.10	0.27	-0.11
Conifer	0.28	0.40	0.39	0.45	-0.10	-0.04	-0.28
TallDeci_Tree	0.29	0.16	0.00	-0.12	0.02	0.38	-0.15
Box	0.18	0.16	0.39	0.06	0.10	-0.09	0.24
Feeder	0.21	0.34	0.35	-0.10	0.13	0.04	0.07
Cat	0.22	0.00	-0.15	-0.11	-0.18	-0.13	0.28
Dog	0.14	0.06	-0.07	-0.06	0.09	0.20	-0.24
Non-Veg500m	-0.02	-0.12	-0.25	-0.25	0.15	0.08	0.11
Traffic_Index500m	0.12	0.34	0.20	0.07	0.06	0.12	0.03

B)

Spring	**Black-capped Chickadee**	**Red-breasted Nuthatch**	**Dark-eyed Junco**	**Blue Jay**	**Black-billed Magpie**	**House Sparrow**	**Rock Dove**
dist_RiverPark	-0.11	0.06	-0.15	0.05	-0.02	0.12	-0.13
dist_Agriculture	-0.21	0.00	0.15	-0.27	0.20	0.13	0.06
Fruit_Tree	0.02	0.32	-0.05	0.12	0.06	-0.12	-0.03
Deci_Fencerow	0.23	-0.03	-0.08	0.07	-0.07	0.22	-0.15
Conifer	0.60	0.13	-0.14	0.34	-0.26	-0.10	-0.29
TallDeci_Tree	0.30	0.14	-0.27	-0.07	0.03	0.42	-0.11
Box	0.24	0.57	0.48	-0.01	-0.18	-0.26	0.23
Feeder	0.40	0.38	0.38	0.03	0.12	-0.13	0.11
Cat	-0.33	-0.22	0.01	-0.18	0.15	-0.18	0.09
Dog	-0.09	-0.18	0.10	-0.19	0.12	-0.02	-0.10
Non-Veg500m	-0.13	-0.17	0.06	-0.42	0.00	0.08	-0.06
Traffic_Index500m	0.19	-0.11	0.00	-0.07	0.16	0.09	0.01