

# Testing the Validity of the Avian Focal Species Approach to Conserve Biodiversity in Urban Forests: Preliminary Report

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## Abstract

A long-term goal of the Georgia Basin Ecosystem Initiative is to promote conservation of biodiversity within the Greater Vancouver Region by focusing on priority habitat requirements. A regional working group led by the Ministry of Water, Land and Air Protection began developing a strategy to support this initiative using indicator species as the primary model. A fundamental assumption of the strategy is that 'biodiversity' and 'habitat quality' are directly associated and can both be assessed by using indicator species. Focal species were identified that 1) were believed to be characteristic of specific sensitive ecosystems and/or limited habitats; 2) were considered reliable indicators of biodiversity; and; therefore, 3) could be used as proxies for habitat quality. The goal of this project is to test the assumptions that a subset of the selected avian focal species can in fact be useful as 'indicators' in mature forests of the Greater Vancouver Region. A total of 69 species were observed across all parks with 22 species individually comprising from 1% to 12% of observations. Of the subset of 10 focal species, only 5 represented greater than 1% of observations and the most abundant was the spotted towhee. Rarefied species richness across all study sites was  $31.1 \pm 4.3$  (mean  $\pm$  SD). The rate of increase in species richness decreased dramatically after approximately 300 observations. Stepwise forward regression analyses resulted in unique habitat models for each of seven focal species. Model R-squared values ranged from 0.190 to 0.805. Additional analyses are ongoing to assess the quality of these environments with respect to the selected focal species, and whether these species act as valid indicators.

## Introduction

The Greater Vancouver Region is an area of high species and habitat diversity that is internationally recognized as ecologically important for a wide diversity of taxa ranging from resident species to wide-ranging and migratory species that use this region for breeding, wintering, and as a critical staging area during migration (Bird Studies Canada 2003). The pressure of human development on the environment is intense; much of the remaining habitat is

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**Citation:** B. Gowans, K. Rothley and C. Thompson. 2007. Testing the Validity of the Avian Focal Species Approach to Conserve Biodiversity in Urban Forests. Preliminary Report. Paper presented at the "Monitoring the Effectiveness of Biological Conservation" conference, 2-4 November 2004, Richmond, BC. Available at: <http://www.forrex.org/events/mebc/papers.html>

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becoming increasingly degraded or fragmented, or has been lost resulting in native wildlife population declines (Marzluff 2001; Donnelly 2002; Lee and Rudd 2003). As a result, new research initiatives are developing strategies to protect biodiversity and monitor population levels of remaining species.

A common approach is to choose a set of 'focal' species as surrogate measures of biodiversity and to evaluate the effectiveness of conservation efforts (Noss et al. 1999). Focal species that are sensitive to habitat degradation are typically termed 'indicator' species such that their status accurately reflects the overall health or quality of the ecosystem, and may be used to detect early signs of environmental change (Landres et al. 1988; Noss et al. 1999, Sterling and Sitnik 1999; Marzluff 2001). Indicator species viability may; therefore, be used as a proxy for ecological conditions that are necessary for the persistence of other less sensitive species in the same habitat. Thus, a common planning strategy is to direct conservation and monitoring efforts towards preserving indicator species (Noss et al. 1999).

A long-term goal of the Georgia Basin Ecosystem Initiative is to promote conservation of biodiversity within the Greater Vancouver Region by focusing on priority habitat requirements. As part of this initiative, the Douglas College Institute of Urban Ecology (Lee and Rudd 2003), in consultation with a regional working group led by the Ministry of Water, Land and Air Protection (MWLAP) developed a conservation strategy with a fundamental assumption that 'biodiversity' and 'habitat quality' are directly associated and can both be assessed by using indicator species. The strategy identified focal species that are 1) believed to be characteristic of specific sensitive ecosystems and/or limited habitats; 2) considered reliable indicators of biodiversity; and 3) would, therefore, be used as proxies for habitat quality.

The focal species approach was developed in large non-urban landscapes (Lambeck 1997) and has had limited testing in small-scale urban settings (Noss et al. 1999; Marzluff 2001; Garson et al. 2002). The goal of this research is to test the assumptions that 7 of the selected avian focal species identified by Lee and Rudd (2003) as indicators of forest habitat (Black-throated Gray Warbler, *Dendroica nigrescens*; Brown Creeper, *Certhia americana*; Pileated Woodpecker, *Dryocopus pileatus*; Red-breasted Nuthatch, *Sitta canadensis*; Rufous Hummingbird, *Selasphorus rufus*; Spotted Towhee, *Pipilo maculatus*; and Townsend's Warbler, *Dendroica townsendi*) are, in fact, valid 'indicators' of biodiversity in mature urban forests of the Greater Vancouver Region. The specific objectives are to:

- measure relative abundance of the selected focal species and other observed species,
- measure a variety of physical and biological parameters that are believed to reflect habitat quality,
- determine the physical and biological characteristics that appear to be most associated with focal species abundance,
- assess whether the selected focal species can act as indicators of mature forest, and
- generate GIS-based maps of priority habitat areas for the focal species.

## Methods

The B.C. lower mainland's lower elevations are located in three biogeoclimatic subzones: Coastal Western Hemlock dry maritime subzone (CWHdm), Coastal Western Hemlock very dry maritime subzone variant 1 (CWHxm1) and the Coastal Douglas Fir moist maritime subzone (CDFmm) (Meidinger and Pojar 1991). Within subzones, Lee and Rudd (2003) described nine major ecosystem classes and subclasses for the Greater Vancouver Region. This study focused on

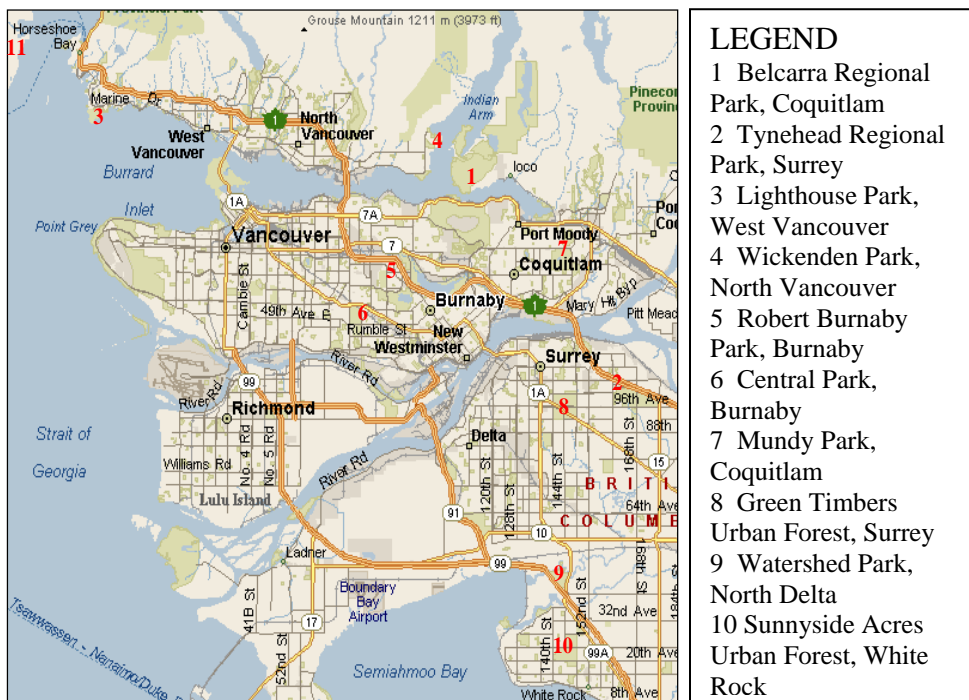
three subclasses in the major class Forest: mature coniferous, mature deciduous and (mature) mixed. These subclasses were chosen because they are among the most dominant classes of forested ecosystems remaining and have a significant diversity of breeding focal species.

Animal surveys concentrated on bird species because 1) they have relatively large-scale habitat requirements; 2) their habitat requirements are relatively well known; 3) they are abundant and visible; and 4) there are well-standardized methods for surveying bird populations. Pileated woodpeckers were selected for special focus to investigate important ecological functions in relation to study site size, disturbance and habitat quality.

## Study Sites

Within 8 municipalities, we selected 10 parks and 1 ecological reserve as study sites (Figure 1) based on criteria such as patch size, forest age and specific landscape parameters, with the objective of surveying an accurate representation of mature forest conditions in the Greater Vancouver Region.

Multiple permanent observation points for conducting bird surveys were established within each study site using a systematic random approach. Numbers of points varied from 2 to 12 at each site depending on patch size and logistical feasibility (Table 1). Points were positioned at least 200 meters apart and 100 meters from any forest edge.



Source: MSN Maps <http://www.mapblast.com>

Figure 1. Map of Greater Vancouver Region indicating study site locations.

Table 1. Bird points established per study site relative to area in hectares (ha).

<b>Park</b>	<b>No. Birdpoints</b>	<b>Area (ha)</b>
Belcarra	10	690
Ecological Reserve 48	8	397
Central	8	89
Green Timbers	10	260
Lighthouse	11	75
Mundy	12	181
Robert Burnaby	4	32
Sunnyside Acres	11	124
Tynehead	8	123
Watershed	10	225
Wickenden	2	16
<b>Total</b>	<b>94</b>	

## Surveys

Standardized field methods were used to document bird species diversity (Hutto et al. 1986; Manuwal and Carey 1991; Krebs 1999; Bibby et al. 2000; Huff et al. 2000; RISC 2003) and measure physical and biological parameters of habitats (James and Shugart 1970; Noon 1981; Bunnell and Vales 1989; Morrison et al. 1992; RISC 2003) and aspects of disturbance (FAO 2002; Rudd et al. 2002).

Bird point surveys were conducted at observation points from 0530h to 1100h between April 30 and July 15. Because the focal species include both migratory and nonmigratory species with different breeding phenologies, this time interval may have biased detectability of some species relative to others; however, because this study focused on relationships between individual bird species and their habitats, not relationships among bird species, any such potential bias was irrelevant. During 10-minute intervals, audiovisual detections of all species were recorded within 100-meter fixed radii of each point during 10-minute intervals. After 1100 h, extensive effort was spent observing pileated woodpeckers to search for nests and roosts.

Habitat sampling was conducted after July 15 to maximize faunal observations during migration and breeding periods, and to avoid disturbance to breeding birds. Vegetation sampling focused on woody species, shrubs, herbaceous and grassland species in circular 0.04 ha (11.28-meter radius) plots surrounding each bird point. In addition to various site-specific variables (i.e. elevation, aspect, slope, mesoslope position, structural stage, crown canopy cover), vegetation type and abundance were characterized by measuring a range of parameters including canopy height and diameter-at-breast-height (dbh) of all woody species, percent cover by vegetation layer, shrub density and species composition, plant and log dispersion, and dominant ground cover type and species. Density, decay class and dbh were measured for all snags in 0.2 ha (25-meter radius) circular plots within which the 0.04 ha habitat plots were centred.

## Analysis

Non-spatial data analyses were performed using SYSTAT Version 10 (SYSTAT 2000) with a rejection level of 0.05. Parametric analyses were conducted only on data which were normally

distributed; all data which were non-normally distributed, and could not be transformed, were subjected to non-parametric analyses.

Diversity was measured by species richness, evenness and heterogeneity metrics (Magurran 1988; Morrison et al. 1992; Krebs 1999; Gotelli and Entsminger 2001). Species richness and the Shannon-Weiner Diversity Index were estimated using the rarefaction method (ECOSIM Version 7.0, Gotelli and Entsminger 2001), during which all samples from different study sites were standardized to the smallest size among sites being compared for any specific analysis. Simpson's Index of Evenness was used to investigate proportional abundance for the site samples independently of species richness.

We investigated the relationships between habitat characteristics and mean bird abundance for all focal species using regression models. Multiple regressions were used to search for a composite of stand attributes that predicted species abundances. Stepwise forward techniques estimated the most significant "statistical" habitat parameters for each bird species ( $\alpha \leq 0.05$ ). We controlled for multicollinearity among independent variables by eliminating the lesser of a significantly correlated pair when Pearson's  $r \geq 0.7$  (Waterhouse et al. 2000; Glantz and Slinker 2001).

## Results

### Avian Species Abundance

In the 11 study sites sampled, 94 bird points were visited from 1 to 7 times ( $5.2 \pm 1.0$  mean  $\pm$  SD). There were 9,202 unique bird observations comprising a total of 69 species. Of those, 22 species individually comprised from 1% to 12% of observations (Table 2a), and cumulatively comprised 89% of all observations. The remaining 47 species individually comprised less than 1% of all observations. The most common species, winter wren (*Troglodytes troglodytes*), comprised only 12.1% of all species observed. Of the 5 focal species representing greater than 1% of observations, the most abundant was the spotted towhee (8.9%). The relative abundances of each of the other observed focal species, including pileated woodpeckers, represented less than 1% of bird observations (Table 2b).

Species composition and relative abundance differed dramatically among sites; this was especially true of indicator species (Table 3). Only 5 focal species ranked among the 5 most abundant species in at least one site. Further, Townsend's warbler, black-throated gray warbler and red-breasted nuthatch ranked in the top 5 most abundant in only a single site each. Both warblers ranked relatively low overall.

### Avian Species Diversity

Rarified species richness across all study sites was  $31.1 \pm 4.3$  (mean  $\pm$  SD). Study sites exhibited little variation (23%) in evenness (Table 4). There was no correlation between species richness and evenness across parks ( $t=0.58$ ,  $df=10$ ,  $P=0.58$ ,  $r^2=0.051$ ). The Shannon-Weiner Index is included for comparison to other studies even though it is ecologically difficult to interpret (Magurran 1988). Species richness was a strong predictor of the Shannon-Wiener Index explaining 86% of the variation of this measure ( $t=8.07$ ,  $df=10$ ,  $P<0.0001$ ,  $r^2=0.86$ ).

Table 2a. Species representing >1% of observations over all study sites including 5 focal species.

<b>Species</b>	<b>% Observations Weighted By Park</b>
Winter Wren	12.08
American Robin	10.01
Swainson's Thrush	8.98
Spotted Towhee	8.90
Pacific-slope Flycatcher	5.44
Brown Creeper	4.91
Chestnut-backed Chickadee	4.26
Pine Siskin	4.00
Golden-crowned Kinglet	3.27
Black-capped Chickadee	3.15
Dark-eyed Junco	3.14
Northwestern Crow	2.93
Townsend's Warbler	2.83
Red-breasted Nuthatch	2.79
Wilson's Warbler	2.34
Western Tanager	2.01
Black-throated Gray Warbler	1.76
Song Sparrow	1.76
Black-headed Grosbeak	1.47
Brown-headed Cowbird	1.30
Red-breasted Sapsucker	1.14
Warbling Vireo	0.99

Gray Shade = Indicator Species

Table 2b. Focal species representing <1% of observations over all study sites.

<b>Other Indicator Species</b>	<b>% Observations Weighted By Park</b>
Rufous Hummingbird	0.63
Pileated Woodpecker	0.37
Cooper's Hawk	0.10
Great Blue Heron	0.04
Yellow Warbler	0.03

Gray Shade = Indicator Species

The total number of bird observations per study site varied from 238 at Wickenden Park to 1333 at Mundy Park (Figure 2). Although none of the curves in Figure 2 reached its maximum value or asymptote, where the slope approximates zero, the rate of increase in species richness decreased dramatically after approximately 300 observations.

### **Species-Habitat Associations**

It is well documented that older mature forests have more open canopies, which usually result in higher structural diversity, and therefore, higher species diversity. Because forest plots with larger total basal area are likely to be older stands, we expected and found a positive correlation between mean total basal area of plots and avian diversity; basal area explains 26% of the variation in species richness ( $r^2=0.263$ ,  $df=10$ ,  $t=3.71$ ,  $P=0.031$ ) (Figure 3).

Preliminary species-habitat models “statistically” predict the mean abundance of each of the focal species in relation to various physical and biological parameters (Tables 5-11). In general, multiple regressions revealed that from 19.0% to 80.5% of the variation in mean avian abundance is predicted by elevation, slope, stand structure and vegetation species.

Table 3. Ranking of the relative abundance of species that were among the five most abundant species in at least one park including focal species. Maximum rank per park varied with species richness.

Species	Belcarra	Central	Ecological Reserve	Green Timbers	Lighthouse	Mundy	Robert Burnaby	Sunnyside Acres	Tynehead	Watershed	Wickenden	Mean
American Robin	5	3	6	2	1	2	*1	3	2	2	5	2.91
Black-capped Chickadee	22	5	18	6	23	5	9	9	6	16	12	11.91
Black-throated Gray Warbler	12	25	5	25	9	19	15	30	27	29	13	19.00
Brown Creeper	7	7	9	5	*5	10	*4	8	14	4	6	7.18
Dark-eyed Junco	11	22	1	18	13	18	15	5	24	11	15	13.91
Northwestern Crow	23	2	17	8	15	15	11	19	10	13	9	12.91
Pine Siskin	13	11	11	10	*5	7	*4	7	12	12	4	8.73
Pacific-slope Flycatcher	3	12	4	8	8	6	7	6	9	8	7	7.09
Red-breasted Nuthatch	15	10	12	15	4	15	14	11	23	7	6	12.00
Red-breasted Sapsucker	4	26	14	27	14	21	19	30	27	29	8	19.91
Song Sparrow	10	13	17	12	25	16	12	14	5	28	16	15.27
Spotted Towhee	19	1	18	4	2	4	*1	1	4	3	2	5.36
Swainson's Thrush	1	4	14	3	6	1	3	4	1	5	3	4.09
Townsend's	10	22	3	11	10	12	9	23	13	28	15	14.18

Warbler												
Winter Wren	2	6	2	1	3	3	2	2	3	1	1	2.36
Gray Shade = Indicator Species												
* = Equal ranking (within a park, equal rank indicates equal relative abundance)												
<i>Italicized numbers</i> = maximum rank given because species were not detected in the park												
Maximum Rank	23	26	18	27	27	27	19	30	27	29	16	

Table 4. Observed and rarified avian species richness, evenness and rarefied species diversity indices for each study site. Data are rarified to the lowest sample size, n = 238 at Wickenden Park to standardize effort across study sites.

Park	Observed Richness	* Rarefaction at sample size = 238		
		Species Richness Rarified Mean*	Simpson's Evenness	Shannon-Weiner Index Rarified Mean*
Lighthouse	51	37.60	0.314	3.08
Wickenden	36	36.00	0.526	3.14
Sunnyside	44	33.51	0.405	3.08
Robert Burnaby	36	32.32	0.434	2.98
Mundy	46	32.02	0.334	2.97
Belcarra	39	31.79	0.293	2.83
Tynehead	43	30.31	0.297	2.83
Green Timbers	40	29.61	0.317	2.84
Central	38	28.83	0.368	2.86
Watershed	36	28.44	0.411	2.91
EcoReserve	27	21.53	0.352	2.46

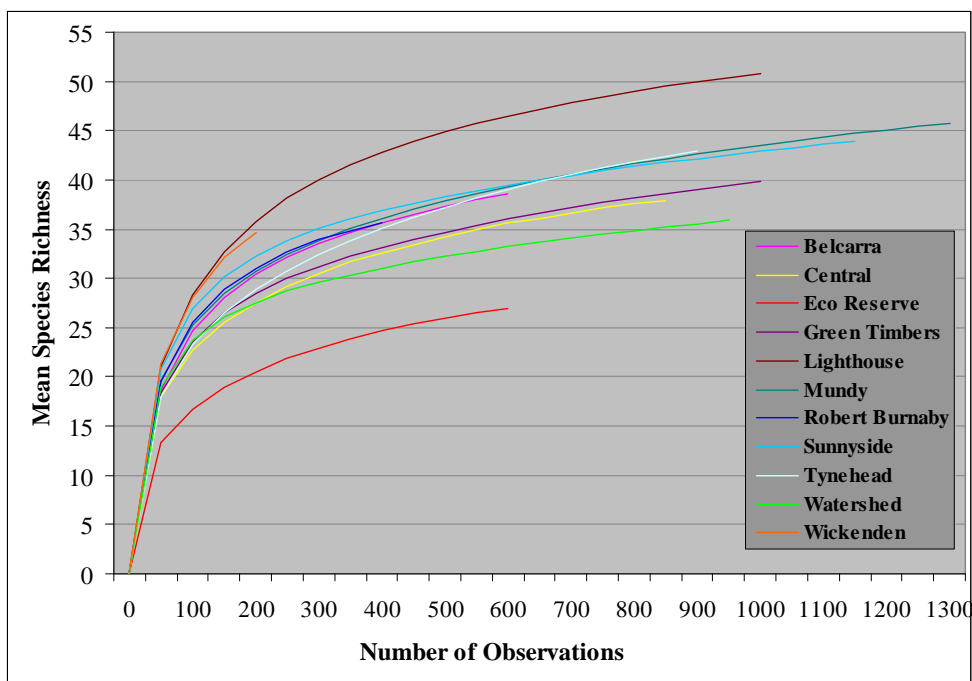


Figure 2. Mean species richness per study site in relation to number of observations.

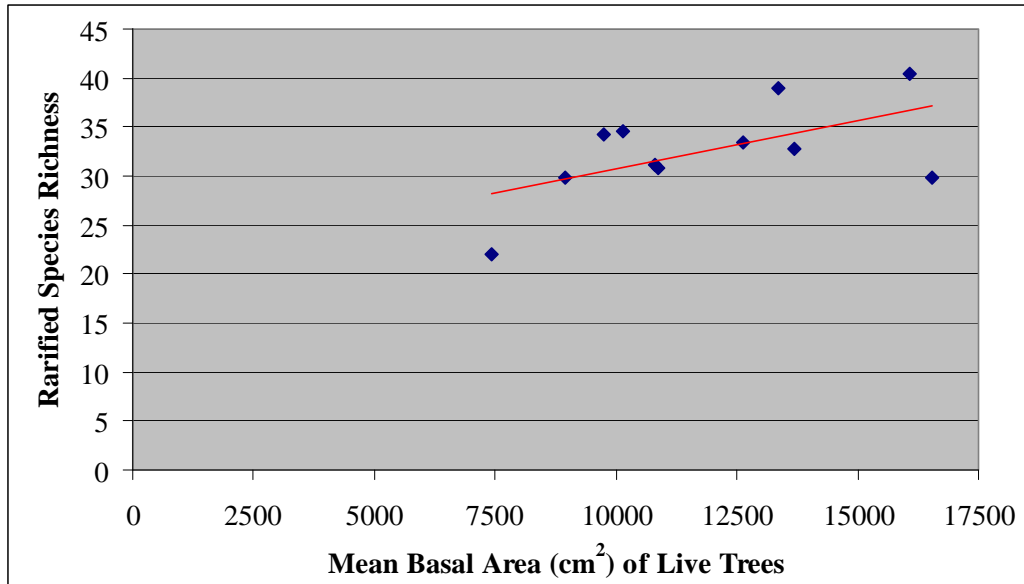


Figure 3. Mean basal area of live trees per study site in relation to rarefied species richness (n=238).

Table 5. Forward regression habitat model for mean black-throated gray warblers detected per bird point.

Predictor	Partial Corr Coeff	Coefficient	Std Coeff	P(2 Tail)
TALL SHRUB COVER	0.445	-0.014	-0.461	0.000
ELEVATION	0.207	0.002	0.340	0.000
SLOPE	0.040	0.018	0.244	0.000
TREE BASAL AREA >30 CM DBH	0.033	0.000	-0.122	0.018
LOW SHRUB COVER	0.025	-0.007	-0.209	0.000
ARBUTUS COUNT >30 CM DBH	0.019	0.510	0.125	0.021
MOSS COVER	0.018	0.006	0.157	0.007
WESTERN HEMLOCK COUNT >30 CM DBH	0.018	-0.025	-0.180	0.001

Dep Var: MEANBGWA N: 94 Squared multiple R: 0.805 Adjusted squared multiple R: 0.787

Table 6. Forward regression habitat model for mean brown creepers detected per bird point.

Predictor	Partial Corr Coeff	Coefficient	Std Coef	P(2 Tail)
DOUGLAS-FIR BASAL AREA >30 CM DBH	0.123	0.000	0.318	0.001
ELEVATION	0.110	-0.003	-0.430	0.000
PROXIMITY TO TRAIL	0.063	-0.005	-0.265	0.003
TOTAL SHRUB COUNT	0.036	-0.002	-0.201	0.031

Dep Var: MEANBRCR N: 94 Squared multiple R: 0.332 Adjusted squared multiple R: 0.302

Table 7. Forward regression habitat model for mean pileated woodpeckers detected per bird point.

Predictor	Partial Corr Coeff	Coefficient	Std Coef	P(2 Tail)
TOTAL LIVE TREES	0.130	0.013	0.252	0.007
SHORE PINE COUNT >30 CM DBH	0.069	0.322	0.312	0.001
DECIDUOUS DEAD TREE BASAL AREA	0.045	0.000	0.310	0.001
LARGEST TREE DBH	0.033	0.001	0.221	0.018
PIWO SIGN – PAPER BIRCH	0.031	-0.120	-0.180	0.048

Dep Var: MEANPIWO N: 94 Squared multiple R: 0.325 Adjusted squared multiple R: 0.326

Table 8. Forward regression habitat model for mean red-breasted nuthatches detected per bird point.

Predictor	Partial Corr Coeff	Coefficient	Std Coef	P(2 Tail)
LOW SHRUB COVER	0.133	0.014	0.367	0.000
MEAN CANOPY HEIGHT	0.057	0.013	0.239	0.013

Dep Var: MEANRBNU N: 94 Squared multiple R: 0.190 Adjusted squared multiple R: 0.172

Table 9. Forward regression habitat model for mean rufous hummingbirds detected per bird point.

Predictor	Partial Corr Coeff	Coefficient	Std Coef	P(2 Tail)
TOTALCOUNT >30 CM DBH	0.079	0.014	0.324	0.001
HERB COVER	0.070	-0.007	-0.322	0.001
WESTERN HEMLOCK COUNT >30 CM DBH	0.061	-0.023	-0.305	0.003
TALL SHRUB COVER	0.057	0.005	0.276	0.004
% CANOPY COVER	0.040	-0.004	-0.211	0.026

Dep Var: MEANRUHU N: 94 Squared multiple R: 0.307 Adjusted squared multiple R: 0.268

Table 10. Forward regression habitat model for mean spotted towhees detected per bird point.

Predictor	Partial Corr Coeff	Coefficient	Std Coef	P(2 Tail)
MEAN LOG DIAMETER	0.204	-0.024	-0.350	0.000
ELEVATION	0.193	-0.006	-0.480	0.000
PROXIMITY TO TRAIL	0.071	-0.008	-0.234	0.004
LOW SHRUB COVER	0.033	0.023	0.258	0.003
HERB COVER	0.026	0.019	0.178	0.029

Dep Var: MEANSPTO N: 94 Squared multiple R: 0.527 Adjusted squared multiple R: 0.500

Table 11. Forward regression habitat model for mean Townsend's warblers detected per bird point.

Predictor	Partial Corr Coeff	Coefficient	Std Coef	P(2 Tail)
ELEVATION	0.361	0.003	0.518	0.000
TALL SHRUB COVER	0.062	-0.009	-0.244	0.002
MEAN CANOPY HEIGHT	0.049	-0.012	-0.210	0.005
LARGEST SNAG DBH	0.030	-0.002	-0.202	0.007
TALL DOMINANT TREE COVER	0.028	-0.007	-0.173	0.022
LOG DISTANCE FROM PLOT CENTRE	0.023	0.041	0.157	0.035

Dep Var: MEANTOWA N: 94 Squared multiple R: 0.553 Adjusted squared multiple R: 0.522

## Discussion

### Avian Species Abundance

An average of 40 bird species was observed in each study site and a total of 69 species was observed across all sites. The three most abundant species were winter wren, American robin and Swainson's thrush (*Catharus ustulatus*), none of which are focal species. Only 5 of the selected focal species; spotted towhee, brown creeper, Townsend's warbler, red-breasted nuthatch and black-throated gray warbler, individually comprised more than 1% of observations (Figures 2a and 2b).

Dense shrub growth, riparian thickets, and shrubby seral stages of forest development characterize spotted towhee breeding habitat; they also are well adapted to urban disturbance and frequently use backyard habitat for breeding and foraging (Greenlaw 1996; Lewis and Rodrick 2004). Our preliminary analyses corroborated this. Breeding populations of both the Townsend's and black-throated gray warbler are limited to substantial patches of forests or large urban parks, most often adjacent to fresh and marine water (Lee and Rudd 2003). This is supported by the fact that these warblers were most abundant in Ecological Reserve 48, a relatively pristine forest and the largest of our study sites. Alternatively, their low abundance in other parks may be an indication of anthropogenic disturbances. These factors may support the usefulness of these warblers as indicators of large undisturbed forested patches. Similarly, the relative abundance of brown creepers and red-breasted nuthatches may indicate the extent of older conifer communities. Brown creepers are expected to function as indicators of specific aspects of forest habitat including tree size and species composition, which in turn likely reflect spider and other arthropod abundance on these trees (Adams and Morrison 1993; Weikel and Hayes 1999). Red-breasted Nuthatches prefer diverse mature stands of coniferous forest with high canopies, large trees and snags greater than 30 cm dbh (Adams and Morrison 1993; Ghalambor and Martin 1999). Our data substantiated this, as nuthatch activity was greatest in Lighthouse and Wickenden Parks, which have the highest percentage of old, large coniferous trees of all the study sites. As with brown creepers, nuthatch abundance also was lowest in Tynehead Park, possibly because of its predominance of deciduous trees.

From the perspective of efficiency, the rarer a species is the more effort it will take to collect statistically robust data on its distribution and abundance, detect relationships between these

data and habitat parameters and; therefore, use such species for monitoring. In more natural forests, the pileated woodpecker's home range size may be up to 1,000 hectares (Bull and Jackson 1995; Aubry and Raley 2002; Lewis and Rodrick 2004) resulting in relatively infrequent and potentially sporadic field observations. The probability of detection within a 10-minute survey interval and 100 meters of a bird point is inversely related to home range size. In this study, pileated woodpeckers comprised only 0.37% of observations across all study sites (Table 2b). Observations often occurred at distances greater than 100 meters from the bird points, after surveys were completed (1100h), coming and going from park boundaries, or later in the season during juvenile dispersal. When these detections are amended to the current analyses, the overall detection level still remains below 1%. This suggests that 100-meter fixed radius bird point surveys are not an effective methodology for collecting data on pileated woodpeckers in urban landscapes, although it was not known prior to the study how pileated woodpecker abundance and behavior might differ in these disturbed environments relative to more pristine sites. Intensive transect surveys for visual and vocal detections of pileated woodpeckers, over a broader range of daylight hours, would likely result in a more comprehensive and accurate evaluation of their habitat use.

These urban/suburban study sites were not so disturbed that their avian and plant communities had a significant exotic component; only 2 exotic plant and 1 exotic bird species were detected. This suggests that our study sites represented relatively intact mature forest. However, indigenous species also can reflect disturbance. For example, Central Park had a much higher percentage of Northwestern crows than other study sites. This is one of many synanthropic species that take advantage of new anthropogenically altered habitat, food supply and nest sites often achieving unusually high abundance and decreasing community evenness in urban areas (Marzluff 2001; Donnelly 2002). Towhee abundance likely reflects its affinity for edges and shrubby habitat in these urban and suburban areas where shrub density and edge areas tend to be higher than in more natural stands. This species may be useful as an inverse indicator of mature forest habitat quality, i.e. an indicator of disturbance. Spotted towhees were most common in Central Park, which we suggest is the most urban and anthropogenically disturbed of the study sites (dense trail system, close proximity to impervious surfaces and dense housing, resident homeless people, extensive human use). They also were absent or nearly so from the two least disturbed sites, Belcarra Park and Ecological Reserve 48.

### **Avian Species Diversity**

Stand development is a complex, long-term process that contributes significantly to vertebrate diversity through the various stages of forest development (Franklin et al. 2002). The three attributes of forest ecosystems; composition, structure and function, change during each successional stage. Analyses of habitat data from these study sites indicated late seral forests ranging from maturation to horizontal diversification stages with increasing species richness.

The relatively higher avian species diversity in Lighthouse and Wickenden Parks is a reflection of the structural diversity associated with older mature and veteran trees, and a more open tree canopy. Ecological Reserve 48 is a relatively large forest that has never been logged or otherwise anthropogenically disturbed. It is technically the oldest stand of all the study sites with the most open understory and extensive moss cover. By the above reasoning, it would normally be expected to have high avian species richness; however, a diverse topography including sheltered gullies and exposed rock bluffs which are subjected to frequent natural disturbances has resulted in a multi-aged stand (Nowacki and Kramer 1998) that is not functionally "old". It also averages 400 meters in elevation, more than 200 meters higher than

the next highest site, Mundy Park. These factors may explain the lower avian diversity at this site. Belcarra Park, which has similar topography, also had relatively low bird species richness. Tynehead is primarily a deciduous riparian forest (64% of trees) which naturally has a more open canopy than sites dominated by coniferous trees, and was expected to have relatively high species richness. Two factors may contribute to its lower diversity: 1) a high percentage of main canopy cover, and 2) the highest density of Himalayan blackberry, an exotic shrub that, although providing food and shelter to a wide range of species, vigorously competes with a diversity of other resident plant species creating environments that are more homogeneous.

The species richness curves (Figure 2) have two implications. After approximately 300 observations, the rate of new species detections declines dramatically. Maximum species richness for each study site can be efficiently and inexpensively estimated by modeling, as explained above, based on relatively few bird observations. Confidence intervals around such estimates will decrease with increasing numbers of observations.

### **Species-Habitat Associations**

The study sites comprised a range of mature forest from predominantly coniferous to mixed coniferous-deciduous to predominantly deciduous stands. Species composition was typical of Coastal Western Hemlock dry maritime (CWHdm), very dry maritime (CWHxm1) and Coastal Douglas Fir moist maritime (CDFmm) biogeoclimatic subzones (Meidinger and Pojar 1991). Only Lighthouse Park with its marine interface contained plant species limited to coastal marine habitat. The general trend in tree diameter and height across sites indicated maturing or late seral stands. There were many very large veteran trees at most of the study sites. The high canopies ranged from the more closed canopy of mature stands to more open stands in the horizontal diversification stage (Franklin et al. 2002) that allows regeneration of understory shrubs and trees. This was evident from the high variation in shrub, forb and moss cover among sites. Snags were relatively small in diameter and represented a mix of coniferous and deciduous species. On average logs were large in diameter. Vine maple persisted in all stands as the dominant understory shrub. Lighthouse and Wickenden Parks were structurally the oldest forests. Central Park and Green Timbers Urban Forest appeared to be the most disturbed sites, respectively, due to trail density, human use, and proximity to high traffic areas and high-density urban land use.

Preliminary stepwise forward regression analyses resulted in unique habitat models for each of seven focal species (Tables 5 – 11). Partial regression coefficients were calculated to indicate the relative importance of each variable to mean bird abundance. Within each model, many significant habitat variables agree with those found to be important to particular species in previous studies while other variables that appear to be important based on our results have not been identified previously and warrant additional attention. For example, in the habitat model for pileated woodpeckers, variables such as stand density, deciduous snag basal area and large tree dbh are consistent with findings in previous research; but shore pine count is unique to this study. The tree species shore pine was only recorded in Lighthouse Park where there was also the highest overall detection rate of pileated woodpecker and where a nesting pair resided, which may explain the significance of shore pine to this species. In more pristine and undisturbed forests, pileated woodpeckers have large home ranges. It is unclear exactly which specific habitat variables in these urban systems may significantly influence behaviour and territory size in relation to habitat quality or extent of fragmentation. Connectivity between suitable forest sites may strongly influence pileated habitat use.

In coastal forests of the Pacific Northwest, brown creepers favor mature to old-growth forest with high closed canopies that contain an abundance of large dead or dying trees for nesting and large live trees with deeply furrowed bark for foraging (Adams and Morrison 1993; Hejl et al. 2002). Our models marginally corroborated this. Although we would expect Townsend's warblers to be positively associated with canopy height and tall dominant tree cover, we may not expect it to be associated in this study to structural features such as log dispersion.

Although these "statistical" models can potentially show the relative importance of each of the habitat variables to each of the focal species, these variables must be evaluated with respect to their biological relevance in order to 1) validate the usefulness of focal species as indicators of habitat quality, and 2) detect potentially unique relationships in urban environments. Similar multiple regressions were conducted on maximum numbers of each of the focal species but the results explained less variation in bird abundance.

## **Preliminary Conclusions**

There are some tentative inferences that can be made from a review of our preliminary results. Our data demonstrated potential economic impediments to collecting a sufficiently robust data set for each of the focal species. Lee and Rudd (2003) listed a set of 9 criteria by which indicator species were selected, including cost-effectiveness of monitoring, and their dependence on and ability to represent specific habitats, i.e., their ability to act as proxies for other species that depend on those habitats. Other selection criteria were mostly, but not entirely, biological and included aesthetic or charismatic value.

Although spotted towhees may act as important indicators of quality habitat for shrub-dependent species, they appear to be positively correlated with structurally similar human-impacted environments, and so also may be important indicators of disturbance. In contrast, both Townsend's and black-throated gray warblers may act as important indicators of more intact forest patches. Pileated woodpeckers may represent a good umbrella species for which to test certain aspects of habitat structure and quality for other species, such as availability of wildlife trees or arthropod abundance, but do not appear suitable for monitoring by fixed radius bird point surveys. Although this method has been used in non-urban habitats by many researchers in the field, there is a need to document results in urban habitats where restricted patch size may alter behaviour in a bird with such a large natural territory size. Similarly, the level of abundance of brown creepers and/or red-breasted nuthatches in a mature forest may be an indication of similar habitat needs being met but on a variety of smaller scales.

Overall, our study sites provided an environment with high species and structural diversity in which to evaluate use by the selected avian focal species. There may be several ways to define 'habitat quality'. For example, one way, is to review similar forest habitat variables at more pristine sites in the same biogeoclimatic subzone, or an alternative method, from the perspective of individual bird species, may be to assess the critical habitat needs for each or a group of focal species and compare these to the habitats in which they occur. The extent to which these study sites may or may not be high quality environments with respect to the selected focal species is yet to be investigated (Meidinger and Pojar 1991; Maraj 1999; Donnelly 2002). We are developing a strategy to rank sites according to habitat quality and disturbance, and will then use correlations between site quality rank and bird abundance to evaluate whether the birds appear to be valid indicators. Detailed habitat descriptions for each of the 7 focal species, as well as a review of important and effective criteria used to select indicator species in previous studies, will facilitate an evaluation of the 9 criteria reported in Lee and Rudd (2003) by which the set of focal species were selected to indicate biodiversity in mature forests of the Vancouver Lower Mainland. We can then begin to assess each of these species as valid indicators to use in future monitoring strategies.

## Acknowledgements

We would like to acknowledge Alton Harestad and Ken Lertzman as well as several biologists at the Ministry of Water, Land and Air Protection and Canadian Wildlife Service, who have provided advice and support during my thesis research. For financial support we would like to thank Pamela Zevit (Como Watershed Group) and the Ministry of Water, Land and Air Protection for providing funding for the 2003 field season, the City of Burnaby for the Doug Drummond Fellowship Award and Simon Fraser University for graduate fellowships and teaching assistantships during my studies. Without the support of the managerial and park staff in the Greater Vancouver Regional District, and in various municipalities, the fieldwork could not have been conducted. Finally, we would like to acknowledge scientific guidance and moral support from our colleague Christopher Thompson, University of Washington.

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