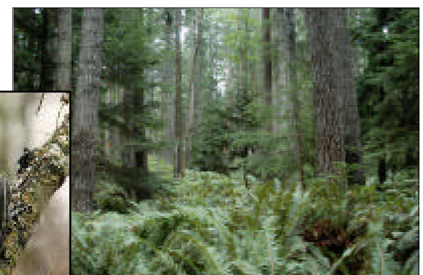
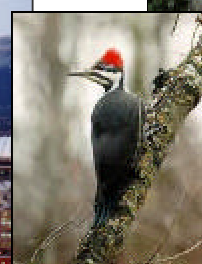
Preliminary Report

Submitted to B.C. Ministry of Water, Land and Air Protection

Testing the Validity of the Focal Species Approach to Conserve Biodiversity In Urban Landscapes



Ecological Reserve 48



Pileated Woodpecker (*Dryocopus pileatus*)

Vancouver, B.C.

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INTRODUCTION

Background

The Greater Vancouver Region is an area of high species and habitat diversity, but also has a relatively high rate of human population growth and development (Lee and Rudd 2002). The overall landscape includes a heterogeneous mosaic of estuaries, fresh and marine waterways, forested uplands, productive lowlands, parklands and urban areas. This region is internationally recognized as ecologically important for a wide diversity of taxa ranging from resident species that may utilize small patches in backyard wildlife habitats to wide-ranging and migratory species that use this region for breeding (e.g. warblers), wintering (e.g. many waterfowl species), and as a critical staging area during migration (e.g. shorebirds) (Bird Studies Canada 2003). Urbanization is likely to be the single most important driver of extinction (Marzluff et al. 2001). The pressure of human development and related activities on the environment in this area is intense; much of the remaining habitat is becoming increasingly developed, degraded, fragmented or lost resulting in native wildlife population declines (Marzluff 2001, Donnelly 2002, Lee and Rudd, 2002). It is urgent, therefore, that measures be developed and implemented to protect the residual habitats in which these species live. As a result, new research initiatives are developing strategies to protect biodiversity and monitor population levels of the remaining species.

A common assumption is that we can choose a set of 'focal' species as surrogate measures to evaluate and achieve conservation of biodiversity (Noss 1999). The key characteristic of a focal species is that its status and trends provide insights to the integrity of the ecological system to which it belongs. A set of focal species represent the range of environments within the area being analyzed. Individual species, or groups of strongly interactive species (Soulé et al 2003), may be identified as focal species. A focal species may utilize habitat that encompasses the needs of many other species ('umbrella' species), play a key role in maintaining community structure or processes ('keystone' species), be sensitive to the changes likely to occur in the area ('indicator' species), and/or otherwise serve as an indicator of ecological sustainability. Some, such as 'flagship' species, may also be highly charismatic stimulating broad support for conservation proposals (Noss 1999).

Focal species that are among the most sensitive to degradation in habitat are typically termed 'indicator' species such that their population status accurately reflects the overall health or quality of the ecosystem and may be used to detect early signs of environmental change or monitor the effects of conservation or restoration projects (Landres *et al*. 1988, Noss 1999, Sterling and Sitnik 1999, Marzluff 2001, Lee and Rudd 2002). Indicator species viability may therefore be used as a proxy for ecological conditions that are necessary for the viability of other species in the same habitat. To ensure conservation of a specific habitat or group of habitats, a suite of indicator species must be monitored whose range of habitat requirements encompasses the full range of environments within the area of concern. A common and proven planning strategy is therefore to direct conservation efforts towards preserving indicator species so that most or all other less sensitive species in the same habitat will also be conserved (Noss 1999).

A general 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 2002), in consultation with a regional working group led by the Ministry of Water, Land and Air Protection (MWLAP), conducted an extensive literature review as well as working sessions with local specialists to begin developing a strategy to support this initiative. Indicator species have been selected as the primary model. In their report to MWLAP, entitled 'Conserving Biodiversity in the Greater Vancouver Region: Indicator Species and Habitat Quality,' Lee and Rudd state a fundamental assumption that 'biodiversity' and 'habitat quality' are directly associated and can both be assessed by using the indicator species model. The report identifies a suite of indicator species within the Greater Vancouver Region that are (1) believed to be characteristic of specific sensitive ecosystems and/or limited habitats; (2) considered to be reliable indicators of biodiversity; and (3) will, therefore, be used as proxies for habitat quality (see Appendix I). Habitat quality is assessed using a combination of biodiversity, structural diversity and levels of disturbance, exotic species and pollutants.

The goal of this research is to test the assumptions that the selected suite of focal species can in fact be useful 'indicators' of biodiversity in the urban, sub-urban and rural Greater Vancouver landscapes within which they are described. The focal species approach was developed in large non-urban landscapes (Lambeck 1997) and has had limited testing in small-scale urban settings such as the Greater Vancouver Region (Noss 1999, Marzluff 2001, Garson et al. 2002). The proposed research will provide an opportunity to validate a critical approach to local conservation and contribute to a body of knowledge in similar systems.

Research Objectives

The specific research objectives are to:

1) measure both presence/absence and/or relative abundance of the selected focal species and other observed species,
2) measure a variety of physical and biological parameters that are believed to reflect habitat quality,
3) determine the physical and biological characteristics that appear to be most associated with focal species abundance
4) assess whether the selected focal species can act as indicators, and
5) generate predictive GIS-based maps of priority habitat areas for focal species both prior to and after completion of field assessments.

METHODS

The B.C. lower mainland's lower elevations are located in the Coastal Western Hemlock Biogeoclimatic Zone (BC Ministry of Forests 2003). Within this zone, Lee and Rudd (2002) described nine major land cover ecosystem classes and associated subclasses for the Greater Vancouver Region. This study has 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 in the Greater Vancouver Region and have a significant diversity of breeding focal species.

To maximize the efficiency of the study within time constraints, and to increase the likelihood of attaining robust statistical results, a subset of the total suite of focal species identified by Lee and Rudd (2002) was chosen for which extensive baseline data already exist regarding their general distribution and habitat preferences. Animal surveys concentrated primarily 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) the methods for surveying bird populations are well standardized. Pileated woodpeckers (*Dryocopus pileatus*) were selected for special focus to assess important ecological functions with relationship to varying park size, disturbance and habitat quality.

Study Sites

Maps were supplied by MWLAP and the Greater Vancouver Regional District, utilizing existing spatial coverage data. Geographic resources in the form of land cover and topographic maps, landsat and aerial photos, and recent false-color digital maps were used for planning fieldwork. After assessing the available greenspaces in the region, ten parks and one reserve were selected for sampling based on criteria such as access logistics, ownership, patch size, forest age and specific landscape parameters with the objective of surveying a valid representation of the physical conditions in each subclass. Study sites were as follows (Figure1):

Greater Vancouver Regional Parks:	Belcarra Regional Park, Coquitlam
	Tynehead Regional Park, Surrey
Municipal Parks:	Lighthouse Park, West Vancouver
	Wickenden Park, North Vancouver
	Robert Burnaby Park, Burnaby
	Central Park, Burnaby
	Mundy Park, Coquitlam
	Green Timbers Urban Forest, Surrey
	Watershed Park, North Delta
	Sunnyside Acres Urban Forest, White Rock
Provincial Ecological Reserve:	Ecological Reserve 48, Bowen Island

LEGEND

1 Belcarra Regional Park
2 Tynehead Regional Park
3 Lighthouse Park
4 Wickenden Park
5 Robert Burnaby Park
6 Central Park
7 Mundy Park
8 Green Timbers Urban Forest
9 Watershed Park
10 Sunnyside Acres Urban Forest
11 Ecological Reserve 48

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

Belcarra Park and Ecological Reserve 48 were chosen as control sites due to their close proximity to other mature forest, large size and relatively low rate of disturbance. Ecological Reserve 48 is approximately 397 hectares of undisturbed forest without trails or roads, no historical logging and relatively old fire damage. It is also approximates the average home range of pileated woodpeckers in the Pacific Northwest (Lee and Rudd 2002, Lewis and Rodrick 2004).

Multiple permanent observation points were established within each study site using a systematic random approach. Numbers of points varied from two to twelve at each site depending on patch size of forested habitat and feasibility regarding survey time (Table 1). Using a global positioning system and landsat images, points were placed at least 200 meters apart and 100 meters from any forest edge. Park maps were used to facilitate access and movement through forests to conduct fieldwork.

Park	# Birdpoints	Area (ha)
Belcarra	10	690
Bowen Ecol. Reserve	8	397
Central	8	89
Green Timbers	10	260
Lighthouse	11	75
Mundy	12	181
Robert Burnaby	4	32(est.)
Sunnyside Acres	11	124
Tynehead	8	123
Watershed	10	225(est.)
Wickenden	2	16(est.)
Total	**94**	

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

Red-breasted nuthatch
(*Sitta canadensis*)

Surveys

Standardized field methods (James and Shugart 1970, Noon 1981, Hutto et al. 1986, Bunnell and Vales 1989, Manuwal and Carey 1991, Morrison et al. 1992, Krebs 1999, Bibby et al. 2000, Huff et al. 2000, RISC 2003) were used to document bird species diversity, physical and biological parameters of habitats (e.g., forest stand characteristics, structural diversity, habitat diversity and plant associations) and levels of disturbance (reflected by patch size, human activity, proximity to roads and trails, abundance of exotic species).

Bird surveys were conducted at observation points from 0530 h to 1100 h and audiovisual detections of all bird species were recorded within 25-, 50-, 100- and >100-meter fixed radii of each point during 5-, 8- and 10-minute intervals. Most bird points were surveyed 6 times between April 30 and July 15. Numbers of people and aircraft observed within the survey interval were recorded to document disturbance. Intense surveys for nests of focal species were conducted after 1100 h or as time permitted during the nesting season, and was supplemented with opportunistic nest observations of all avian species. A disproportionate effort was spent observing pileated woodpeckers to search for nests and roosts, and record nesting success. All other non-avian species, exotic species and unusual microhabitats detected along trails or predetermined routes within study sites were documented throughout the research period.

Habitat sampling focused on vascular plants and major life forms of the vegetation community (e.g., woody species, shrubs, herbaceous and grassland species) in 0.04 ha (11.28-meter radius) circular plots surrounding each bird observation point at each of the eleven study sites. In addition to various site-specific variables (elevation, aspect, slope, mesoslope position, structural stage, etc.), vegetation type and abundance was 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. Shrub species which were the first, second, and third most abundant within plots were recorded as Dominant 1, 2, and 3, respectively. To more accurately assess wildlife tree availability; density, wildlife class and diameter-at-breast-height (dbh) was measured for all snags in larger 0.2 ha (25-meter radius) circular plots within which the 0.04 ha habitat plots were nested. Field equipment included binoculars, laser rangefinder, altimeter, clinometer, compass, appropriately gauged meter tapes, reference charts and field guides to facilitate these measurements. Estimating percent cover by vegetation layer was completed within each plot using an ocular tube and cover comparison charts (RISC 2003). A moosehorn densiometer was used to measure crown canopy cover. Digital photographs were taken at each sampling plot centre. Vegetation sampling was conducted after July 15 to maximize faunal observations during migration and breeding periods when animals were naturally more active and vocal, and to avoid disturbance to breeding habitat.

Analysis

Diversity was measured by species richness, evenness and heterogeneity metrics (Magurran 1988, Morrison et al. 1992, Krebs 1999, Gotelli and Entsminger 2001). The Shannon-Weiner Index of heterogeneity has been criticized by Magurran (1988), Krebs (1999), Gotelli and Entsminger (2001) and others as not being either biologically or statistically meaningful since it cannot explain whether differences between treatments are due to variations in richness, evenness, both or the data collection methodology. However, since it has been widely used for decades to measure species diversity, I have included it so that these results may be compared to previous studies. Species richness and the Shannon-Weiner Diversity Index were estimated using the rarefaction method (ECOSIM Version 7.0, Gotelli and Entsminger 2001) to standardize all samples from different study sites to a common sample size of the same number of individuals. Simpson's Index of Evenness, sensitive to both rare and common species in the community, was used to investigate evenness for the site samples independently of species richness. Evenness estimates were not rarefied since it was both not possible in the EcoSim software but also unnecessary since they are relatively insensitive to differences in sample size (Krebs 1999).

Many exploratory descriptive and inferential statistics have been conducted to summarize and evaluate primary species-habitat relationships. The results of these analyses form the basis for future additional in-depth comparisons and evaluations of habitat quality parameters, focal species-habitat relationships and subsequent indicator validity.

Non-spatial data analyses were performed in SYSTAT Version 10 software (SYSTAT 2000) using a rejection level of 0.05. All data subjected to parametric tests were tested for normality prior to evaluation. Non-normally distributed data were transformed into normal distributions or tested with non-parametric methods. Spatial information will be analyzed using Arcview GIS software (ESRI, 1999).

RESULTS

Avian Species Abundance

In the 11 study sites sampled, 94 bird points were visited from 1 to 7 times with a mean rate of 5.23 ± 0.96 (standard deviation) (Figure 2). There were a total of 9,671 bird observations across parks and of these, 9, 202 represented unique individual birds, the difference being accounted for by movement of specific individuals within plots during the 10-minute survey interval. A total of 69 avian species were identified for all study sites combined with 0.21% unidentified observations. Of the 18 indicator species identified by Lee and Rudd (2002), 10 species were observed during the bird point surveys (Table 3a) with 1 rare observation of a yellow warbler (*Dendroica petechia*) in unsuitable habitat. The remaining nine are normally found in mature forest habitat and will be the focus of this report.

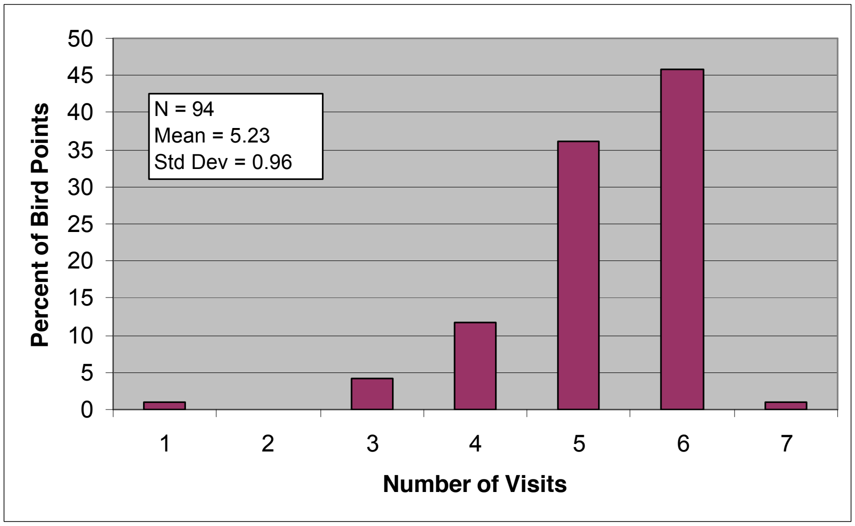
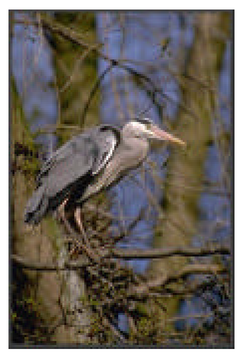


Figure 2. Number of visits to bird points over all study sites.

The only red-listed species observed during the study, double-crested cormorant (*Phalacrocorax auritus*) (Table 2), was seen in the pond at Green Timbers Urban Forest. Of the blue-listed species, Caspian terns (*Sterna caspia*) were observed at Watershed Park, band-tailed pigeons (*Columba fasciata*) were observed at Belcarra Park, Mundy Park, and Sunnyside Urban Forest, and great blue herons (*Ardea herodias fannini*) were observed at Green Timbers Urban Forest, Mundy and Tynehead Parks. The only exotic species observed, European starling (*Sturnus vulgaris*), was observed at Lighthouse, Wickenden, Tynehead, and Central Parks. A list of all avian species detected within each study site both during and after bird point surveys is included in Appendix II.

Species	Listed in B.C.	Listed in the Chilliwack Forest Distr	Observed during bird surveys
Red-Listed			
Double-crested Cormorant	*		
Blue-Listed			
Great Blue Heron	*	*	*
Band-tailed Pigeon	*	*	*
Caspian Tern	*	*	
Exotic			
European Starling	*		*



Great Blue Heron (*Ardea herodias*)

Table 2. Bird species observed both during and outside of bird point surveys that are (1) listed as red (endangered or threatened) or blue (of special concern) in B.C. and in the Chilliwack Forest District, or (2) exotic.

Tables 3a and 3b list species comprising greater than 1% of all observations across all study sites. Data are presented both weighted unequally, i.e. regardless of the number of total observations in each park during bird point surveys, and weighted equally, i.e. giving each park an equal weight, regardless of the number of unique bird observations, in calculation of species composition over all parks. The similarities between the equally weighted and unequally weighted results may reflect the overall similar relative proportions of each species among parks during bird point surveys, i.e. common species in one park tended to also be common in other parks. Only 22 of 69 total species identified (Table 3a), and 5 of the 9 relevant focal species (indicated in red), were observed greater than 1% of the time. The most common species, winter wren (*Troglodytes troglodytes*), comprised only 12.08%

of all species observed. The most abundant focal species across study sites is the spotted towhee (*Pipilo maculatus*) (8.90%). The relative abundances of 5 focal species, including pileated woodpeckers, represent less than 1% of the total bird point observations (Table 3b).

Species	Parks Weighted Unequally	Parks Weighted Equally
Winter Wren	11.93	12.08
American Robin	10.63	10.01
Swainson's Thrush	9.16	8.98
Spotted Towhee	9.22	8.90
Pacific-slope Flycatcher	5.13	5.44
Brown Creeper	4.83	4.91
Chestnut-backed Chickadee	4.21	4.26
Pine Siskin	3.84	4.00
Golden-crowned Kinglet	3.21	3.27
Black-capped Chickadee	3.60	3.15
Dark-eyed Junco	2.97	3.14
Northwestern Crow	2.99	2.93
Townsend's Warbler	2.63	2.83
Red-breasted Nuthatch	2.78	2.79
Wilson's Warbler	2.43	2.34
Western Tanager	1.96	2.01
Black-throated Gray Warbler	1.46	1.76
Song Sparrow	1.88	1.76
Black-headed Grosbeak	1.52	1.47
Brown-headed Cowbird	1.51	1.30
Red-breasted Sapsucker	0.82	1.14
Warbling Vireo	1.05	0.99

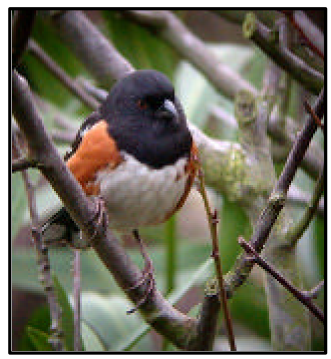
Red = Indicator Species

Table 3a. Species representing >1% of observations over all study sites.

Other Indicator Species	Parks Weighted Unequally	Parks Weighted Equally
Rufous Hummingbird	0.73	0.63
Pileated Woodpecker	0.41	0.37
Cooper's Hawk	0.13	0.10
Great Blue Heron	0.05	0.04
Yellow Warbler	0.03	0.03

Red = Indicator Species

Table 3b. Balance of selected indicator species, each representing <1% of observations over all study sites.



Spotted Towhee
(*Pipilo maculatus*)

Table 4 shows a ranking of the 5 most common species within each park including indicator species. The objective of this analysis was to investigate how the relative abundance of common species differed among parks and especially how indicator species ranked within the top 5 ranking species. Relative abundance of some species differed considerably among parks. The most common species, i.e. winter wren and American robin (*Turdus migratorius*) were the most similar in abundance. Only 5 indicator species are represented in the 5 most abundant species in any park, and only two of these are among the top ten most common species over all parks. Further, Townsend's warbler (*Dendroica townsendi*), black-throated gray warbler (*Denroica nigrescens*) and red-breasted nuthatch (*Sitta canadensis*) rank in the top 5 most abundant in only a single park each. Both warblers rank relatively low overall. The most abundant indicator species is the spotted towhee followed by the brown creeper (*Certhia Americana*). It is interesting to note that spotted towhees rank very low in both control sites, Belcarra Park and Ecological Reserve 48.

Species	Belcarra	Central	Eco 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 Warbler	10	22	3	11	10	12	9	23	13	28	15	14.18
Winter Wren	2	6	2	1	3	3	2	2	3	1	1	2.36
Max Rank	23	26	18	27	27	27	19	30	27	29	16	

Red = Indicator Species
* = Equal ranking (within a park, equal rank indicates equal relative abundance)
Italicized numbers = maximum rank given because species were not detected in the park

Table 4. 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. Mean rank was calculated to compare focal species abundance to all species.

Avian Species Diversity

Mean rarified species richness across all study sites was 31.09. Lighthouse Park had the highest species richness and Ecological Reserve 48 had the lowest, roughly half the value of Lighthouse (Table 5). In fact, Lighthouse and Watershed Parks were significantly different in species richness than most other study sites (Table 6). Ecological Reserve 48 on Bowen Island was significantly lower than all other parks.

Evenness was highest in Wickenden Park and lowest in Belcarra Park. Study sites exhibited minimal variation as shown by a 23% range between 0.297 and 0.526. There was no correlation between species richness and evenness across parks ($t=0.58$, $P=0.58$, $r^2=0.051$).

* Rarefaction at sample size = 238				
Park	**Observed Richness**	**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

Table 5. Observed and rarified avian species richness, species 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.

Species Richness t-test pairwise comparisons											
	Belcarra	*Central*	*Eco Reserve*	*Green Timbers*	*Lighthouse*	*Mundy*	*Robert Burnaby*	*Sunnyside*	*Tynehead*	*Watershed*	*Wickenden*
Belcarra	-	ns	*	ns	*	ns	ns	ns	ns	*	ns
Central		-	*	ns	*	ns	ns	ns	*	*	*
Eco Reserve			-	*	*	*	*	*	*	*	*
Green Timbers				-	ns	ns	ns	*	*	*	*
Lighthouse					-	*	*	*	*	*	ns
Mundy						-	ns	ns	ns	*	ns
Robert Burnaby							-	ns	ns	ns	ns
Sunnyside								-	ns	*	ns
Tynehead									-	*	ns
Watershed										-	*
Wickenden											-

55 Pairwise comparisons
Experimentwise significance level by Dunn-Sidak correction (Sokal and Rohlf 1995) is
1-(1-0.05)^1/55 = 0.00093

Table 6. Species richness compared among parks, "ns" means not significant at P=0.00093.

The index of heterogeneity and therefore diversity was highest in Wickenden Park (3.14) and second highest in Lighthouse Park (3.08) and Sunnyside Urban Forest (3.08). Ecological Reserve 48 was the least diverse (2.46). To provide some perspective, Krebs (1999) states that the biological maximum does not seem to exceed 5.0 in practice. The Ecological Reserve 48 was significantly different than all other parks except Belcarra (Table 7). As was evident in the species richness analyses, the parks on the tails of the distribution tended to show the most differences from other parks. A linear regression of rarified mean Shannon-Wiener Index on rarified mean species richness yielded a highly significant positive relationship. Species richness is a strong predictor of Shannon-Wiener Index explaining 86% of the variation of this measure ($t=8.07$, $P<0.0001$, $r^2=0.86$).

Shannon-Weiner Index t-test pairwise comparisons	Belcarra	Central	Eco Reserve	Green Timbers	Lighthouse	Mundy	Robert Burnaby	Sunnyside	Tynehead	Watershed	Wickenden
Belcarra	-	ns	*	ns	*	*	*	*	ns	ns	*
Central		-	*	ns	*	*	*	*	ns	*	*
Eco Reserve			-	*	*	*	*	*	*	*	*
Green Timbers				-	ns	*	*	*	ns	*	*
Lighthouse					-	*	ns	ns	*	*	ns
Mundy						-	ns	*	*	*	ns
Robert Burnaby							-	ns	*	ns	*
Sunnyside								-	*	*	ns
Tynehead									-	*	*
Watershed										-	*
Wickenden											-

55 Pairwise comparisons
Experimentwise significance level by Dunn-Sidak correction (Sokal and Rohlf 1995) is
1-(1-0.05)^1/55 = 0.00093

Table 7. Shannon-Wiener Indices of species diversity compared among parks, "ns" means not significant at P>0.00093.

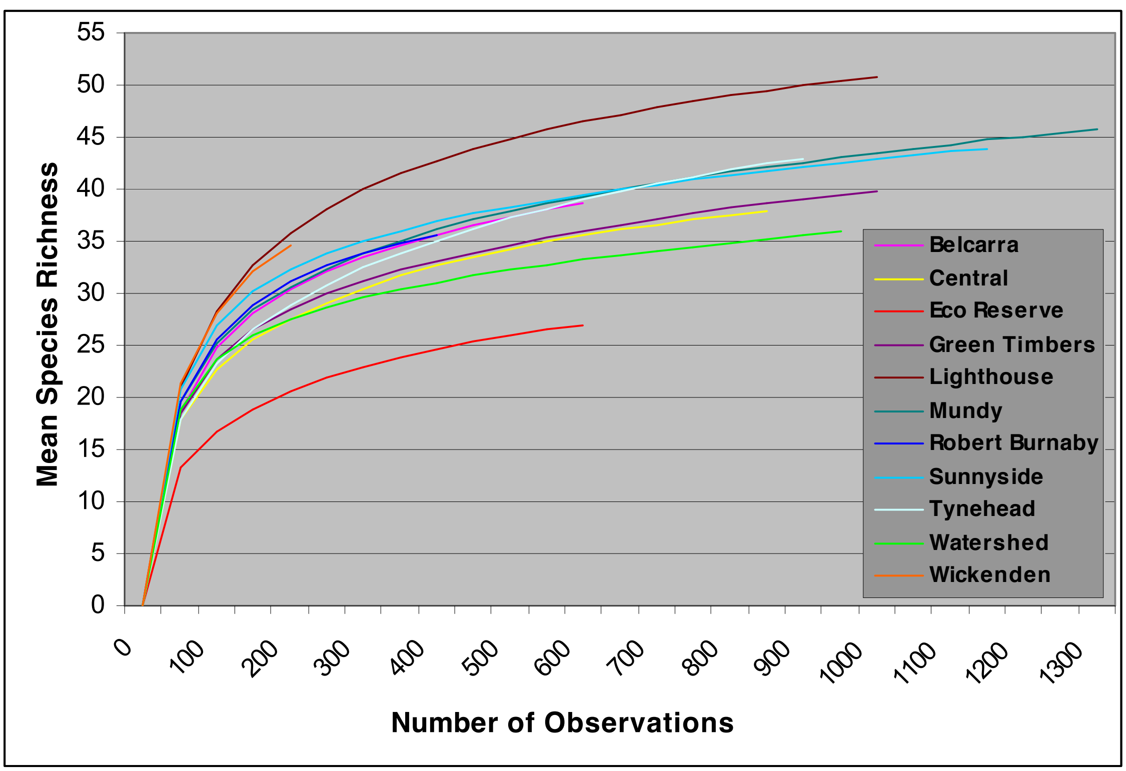
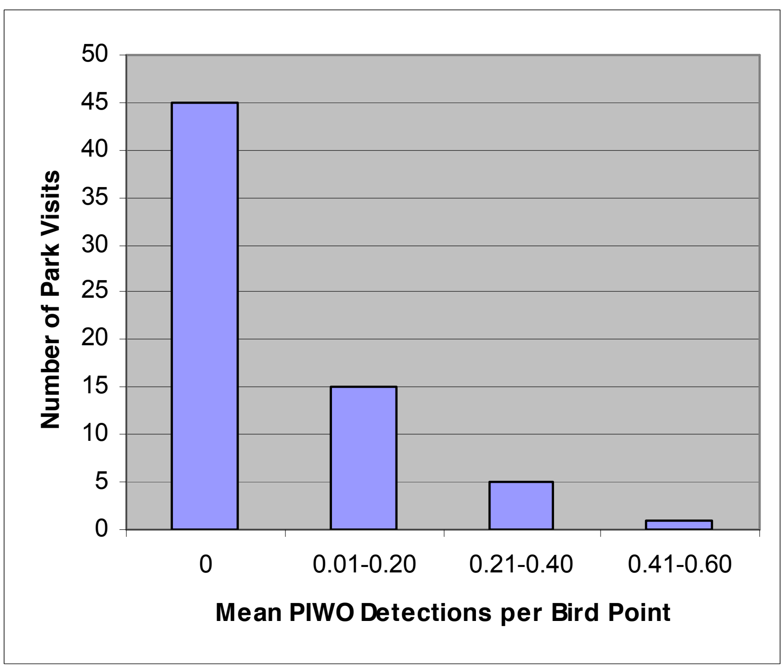


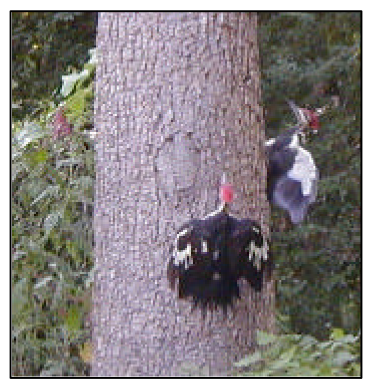
Figure 3. Mean species richness per study site in relation to number of observations.

The total number of bird observations per study site varied from 238 at Wickenden to 1333 at Mundy (Figure 3). As presented in part above (Tables 5 and 6), there is significant variation among parks in the rate at which species richness increases in relation to number of observations. Although none of the curves in Figure 3 has reached its maximum value (asymptote) where the slope approximates zero, the rate of increase in species richness decreases dramatically after approximately 300 observations.

Activity of Selected Focal Species

Over the course of this study period Pileated woodpeckers were detected 82 times, but more than half of these detections were beyond 100 meters (m) from bird points. However, because standard protocol requires that only detections within 100 m be included for analysis, detections beyond 100 m were excluded from the results presented below. Pileated woodpeckers were detected relatively rarely within 100 m during bird point surveys in the study sites visited (Table 3b). In fact, they were detected during only one-third (21 of 66) of all survey days (Figure 4), and at only 6.1% of bird point surveys. Mean pileated woodpecker activity varied among study sites, being highest at Lighthouse and Tynehead Parks. In contrast, activity was low at Watershed Park and non-existent at Belcarra Park, Wickenden Park and Green Timbers Urban Forest (Figure 5) during surveys. Activity was significantly different among study sites (Kruskal-Wallis test, 25.76, df = 10, P = 0.004) but was so variable among visits within each study site that no statistically significant differences were detected among study sites in post-hoc Mann-Whitney U pair-wise comparisons (Table 8). Significance values are given for those below P = 0.05 to indicate potential trends although the experiment-wise rejection level was P = 0.00093. Under these criteria, Lighthouse is significantly different than most other parks.





Pileated Woodpecker
(*Dryocopus pileatus*)

Figure 4. Pileated woodpecker detections in relation to number of study site visits.

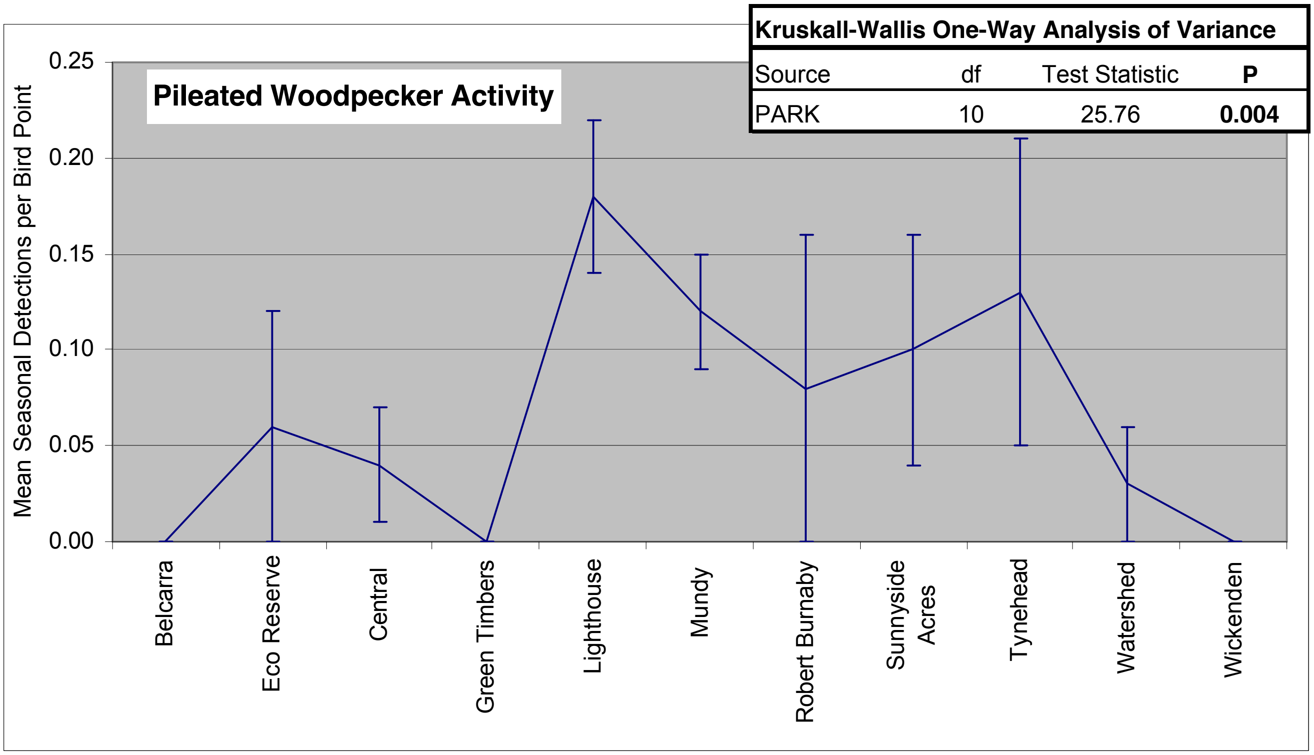


Figure 5. Mean number of seasonal detections (± SE) of pileated woodpeckers per visit to each bird point at each study site.

Mann-Whitney Pair-wise comparisons

	Belcarra	Central	Eco Reserve	Green Timbers	Lighthouse	Mundy	Robert Burnaby	Sunnyside	Tynehead	Watershed	Wickenden
Belcarra	-	ns	ns	ns	0.002	ns	ns	ns	ns	ns	ns
Central		-	ns	ns	0.022	ns	ns	ns	ns	ns	ns
Eco Reserve			-	ns	0.046	ns	ns	ns	ns	ns	ns
Green Timbers				-	0.002	0.007	ns	ns	ns	ns	ns
Lighthouse					-	ns	0.046	ns	ns	0.025	0.002
Mundy						-	ns	ns	ns	ns	0.007
Robert Burnaby							-	ns	ns	ns	ns
Sunnyside Acres								-	ns	ns	ns
Tynehead									-	ns	ns
Watershed										-	ns
Wickenden											-

55 Pairwise comparisons
P values less than 0.05 are reported above but are not significant
Experimentwise significance level by Dunn-Sidak correction (Sokal and Rohlf 1995) is
1-(1-0.05)^1/55 = 0.00093

Table 8. Pileated woodpecker activity compared among parks, "ns" means not significant at P>0.00093.

Species	Belcarra	Bowen EcoRes	Central	Green Timbers	Lighthouse	Mundy	Robert Burnaby	Sunnyside Acres	Tynehead	Watershed	Wickenden	TOTAL
Red Alder	0	15	1	3	1	14	1	7	1	0	0	43
Western Redcedar	8	1	0	1	0	0	0	0	0	2	0	12
Paper Birch	0	0	0	1	0	2	0	0	0	2	0	5
Douglas-fir	6	2	2	2	5	8	0	21	0	11	0	57
Western Hemlock	2	0	0	2	1	3	0	0	4	0	3	15
Total	16	18	3	9	7	27	1	28	5	15	3	132

Table 9. Number of trees by species used by pileated woodpeckers at each study site. The number of bird points varies among study sites and therefore may influence comparison among parks but not among tree species.

Pileated woodpeckers appeared to use primarily Douglas-fir and red alder for foraging, nesting or roosting (Table 9). Although, these are the most abundant coniferous and deciduous species available, further statistical analysis will be necessary to evaluate pileated woodpecker preferences for these tree species. Excavations were most commonly detected in Mundy Park and Sunnyside Urban Forest where there were nests present. In contrast, excavations in Lighthouse Park were low even though there was also a nest present there.

There were no spotted towhees detected in Ecological Reserve 48 over the field season and very low detections in Belcarra Park; both are control sites (Figure 6). These detections were significantly lower than those in some other parks (Table 10). Other parks did not differ significantly from one another including Central Park which had the highest number of detections.

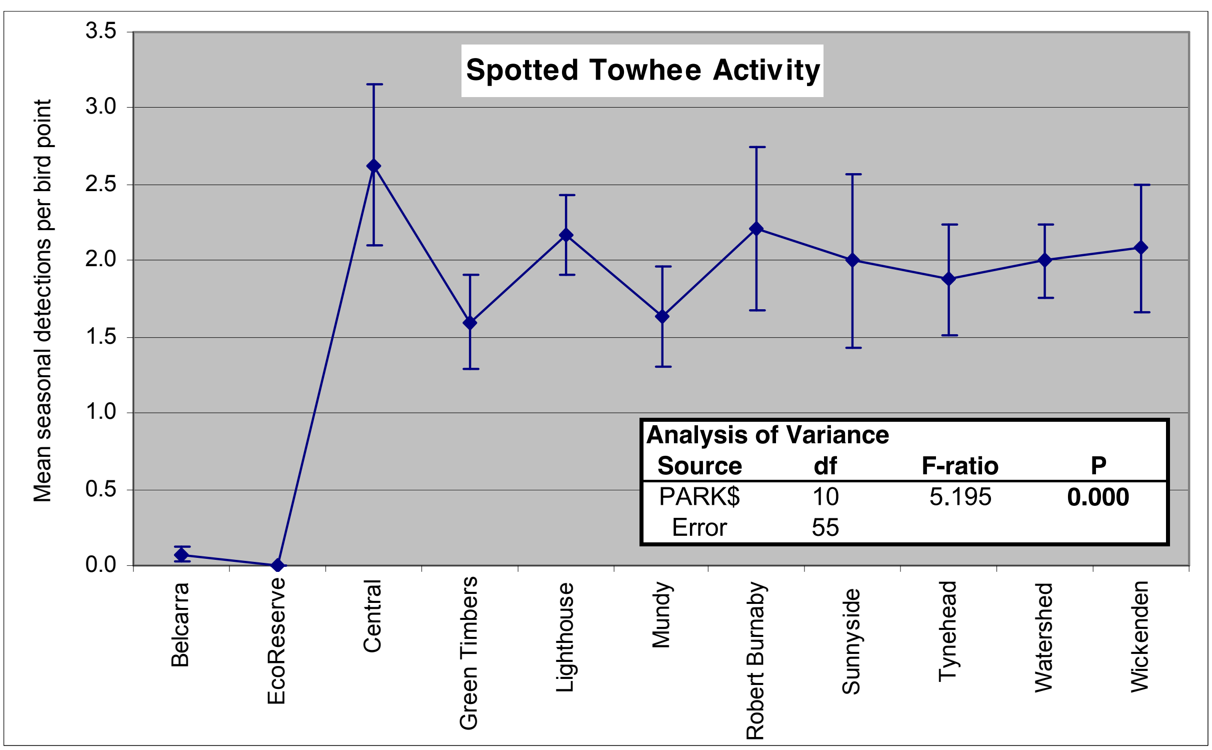


Figure 6. Mean number of seasonal detections (± SE) of spotted towhees per visit to each bird point at each study site.

Bonferroni Adjusted Pair-wise comparisons	Belcarra	Central	Eco Reserve	Green Timbers	Lighthouse	Mundy	Robert Burnaby	Sunnyside	Tynehead	Watershed	Wickenden
Belcarra	-										
Central	0.0006	-									
Ecoreserve	ns	0.0004	-								
Green Timbers	ns	ns	ns	-							
Lighthouse	ns	ns	0.007	ns	-						
Mundy	ns	ns	ns	ns	ns	-					
Robert Burnaby	0.0091	ns	0.006	ns	ns	ns	-				
Sunnyside Acres	ns	ns	ns	ns	ns	ns	ns	-			
Tynehead	ns	ns	ns	ns	ns	ns	ns	ns	-		
Watershed	ns	ns	ns	ns	ns	ns	ns	ns	ns	-	
Wickenden	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	-

Table 10. Spotted towhee activity compared among parks, "ns" means not significant at P>0.05.

Analysis of variance showed that there were significant differences in brown creeper activity among parks (Figure 7) however post-hoc tests indicated the only parks that differed significantly from each other were Tynehead and Watershed Parks (Table 11). Brown creeper detections were highest in Watershed and Robert Burnaby Parks and lowest in Tynehead Park and Ecological Reserve 48.

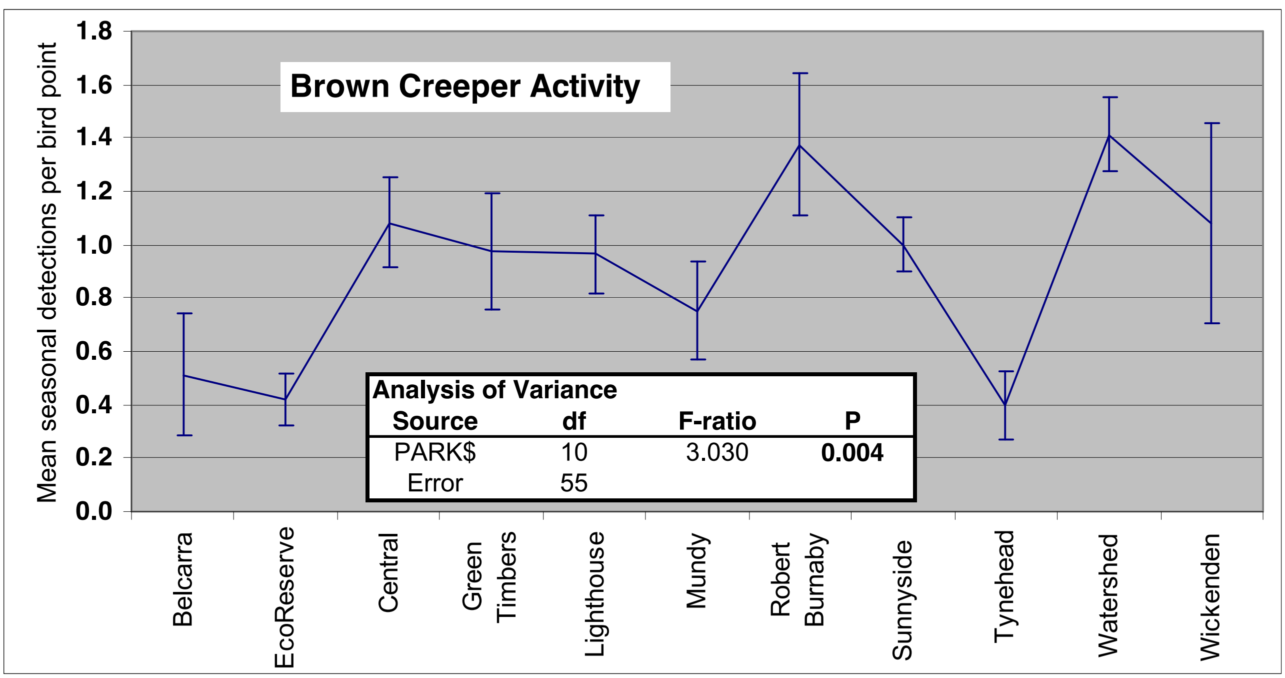


Figure 7. Mean number of seasonal detections (± SE) of brown creepers per visit to each bird point at each study site.

Bonferroni Adjusted Pair-wise comparisons	Belcarra	Central	Eco Reserve	Green Timbers	Lighthouse	Mundy	Robert Burnaby	Sunnyside	Tynehead	Watershed	Wickenden
Belcarra	-										
Central	ns	-									
Ecoreserve	ns	ns	-								
Green Timbers	ns	ns	ns	-							
Lighthouse	ns	ns	ns	ns	-						
Mundy	ns	ns	ns	ns	ns	-					
Robert Burnaby	ns	ns	ns	ns	ns	ns	-				
Sunnyside Acres	ns	ns	ns	ns	ns	ns	ns	-			
Tynehead	ns	ns	ns	ns	ns	ns	ns	ns	-		
Watershed	ns	ns	ns	ns	ns	ns	ns	ns	0.042	-	
Wickenden	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	-

Table 11. Brown creeper activity compared among parks, "ns" means not significant at P>0.05.

Red-breasted nuthatch detections were highest in Wickenden and Lighthouse Parks and lowest in Tynehead Park (Figure 8). Activity was also low in the two control sites, Belcarra Park and Ecological Reserve 48. Analysis of variance indicated significant differences among parks and subsequent pair-wise comparisons showed that Wickenden and Lighthouse differed from most other parks (Table 12) including Tynehead Park. Since Watershed Park has relatively high activity, it also differed significantly from Tynehead Park.

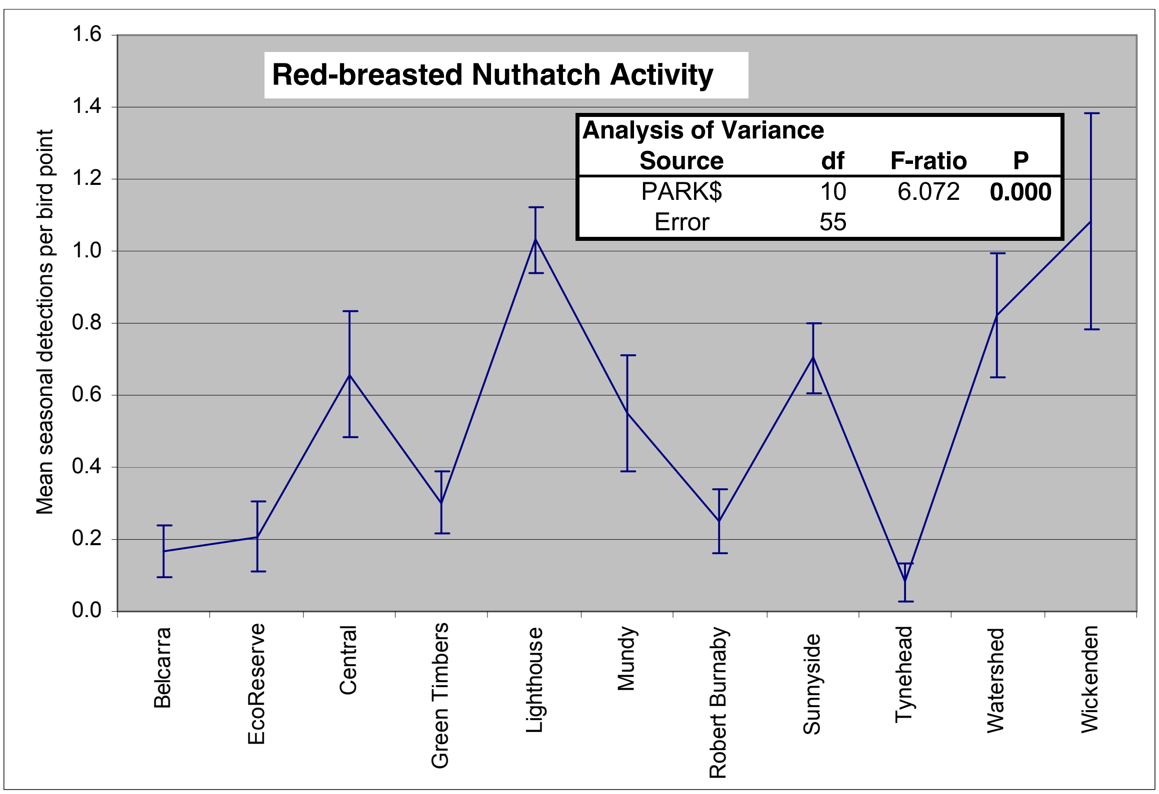


Figure 8. Mean number of seasonal detections (± SE) of red-breasted nuthatches per visit to each bird point at each study site.

Bonferroni Adjusted Pair-wise comparisons											
	Belcarra	Central	Eco Reserve	Green Timbers	Lighthouse	Mundy	Robert Burnaby	Sunnyside	Tynehead	Watershed	Wickenden
Belcarra	-										
Central	ns	-									
Ecoreserve	ns	ns	-								
Green Timbers	ns	ns	ns	-							
Lighthouse	0.0046	ns	0.009	0.038	-						
Mundy	ns	ns	ns	ns	ns	-					
Robert Burnaby	ns	ns	ns	ns	0.017	ns	-				
Sunnyside Acres	ns	ns	ns	ns	ns	ns	ns	-			
Tynehead	ns	ns	ns	ns	0.001	ns	ns	ns	-		
Watershed	ns	ns	ns	ns	ns	ns	ns	ns	0.0333	-	
Wickenden	0.002	ns	0.004	0.017	ns	ns	0.008	ns	0.0005	ns	-

Table 12. Red-breasted nuthatch activity compared among parks, "ns" means not significant at P>0.05.

Nests	Belcarra	Bowen EcoReserve	Central	Green Timbers	Lighthouse	Mundy	Robert Burnaby	Sunnyside Acres	Tynehead	Watershed	Wickenden	Total
AMRO					2	1			2	2		7
BCCH								2	2		1	5
BEWR			1									1
BHGR									1			1
BRCR							1	3		3		7
BUSH				1								1
CBCH	1				1	1				1		4
DEJU		1										1
DOWO						1						1
HAWO	1		1	1	1	3		2				9
NOFL					2							2
PISI				1								1
PIWO					1	1		1				3
RBNU			1					1		1		3
RBSA	5				4	2					1	12
RTHA							1	1				2
RUHU				2						2		4
SPTO						1		1				2
SWTH				2					2			4
WIWR		1				1						2
	7	2	3	7	11	11	2	11	7	9	2	72
											72	

Table 13. Nests found during the 2003 field season. Highlighted species are indicators.

A total of 72 nests were found within the 11 study sites (Table 13). Due to logistical constraints, nest searches were not intensive and were conducted primarily for indicator species, time permitting. Some nests were discovered opportunistically while conducting bird surveys or moving between bird points. The objective was to further document use of the study sites by the selected focal species. This data set is an extremely modest representation of breeding bird activity or nest density within these study sites.

Physical and Biological Habitat Parameters

Live Trees

The percentage composition of tree species within plots among study sites is given in Table 14. The general trend was a predominance of coniferous trees; Douglas-fir, Western hemlock and Western redcedar, in order of decreasing abundance. This is typical of slightly drier, disturbed Coastal Western Hemlock forests although each park has its own unique composition. Wickenden Park and the two control sites, Belcarra Park and Ecological Reserve 48, had the highest percentage of conifer trees. The habitat plots in Belcarra and Wickenden Parks were almost pure Western hemlock. Tynehead Park differed as a deciduous-dominated forest, consisting primarily of red alder mixed with a smaller percentage of Western hemlock. Green Timbers Urban Forest and Robert Burnaby Park appear to be mixed forests.

% Tree species composition among parks											
Species	**Belcarra**	**Bowen EcoRes**	**Central**	**Green Timbers**	**Lighthouse**	**Mundy**	**Robert Burnaby**	**Sunnyside Acres**	**Tynehead**	**Watershed**	**Wickenden**
Douglas-fir	5.79	68.04	35.16	28.42	30.74	23.08	3.23	59.51	1.39	38.66	1.63
Western hemlock	85.64	14.95	18.75	13.16	20.95	28.00	14.52	2.45	22.92	7.06	86.99
Western redcedar	6.05	12.89	16.41	15.26	29.39	22.77	29.03	4.29	4.86	40.89	11.38
Grand fir			0.78	1.58							
Sitka spruce									6.94		
Shore pine					6.08						
Western white pine		0.52									
Red alder	2.02	3.61	10.94	15.26	0.68	17.54	8.07	18.41	47.22	4.09	
Bigleaf maple	0.25		5.47	1.05	2.70	1.23	37.10	1.84	4.86	2.60	
Paper birch			10.16	14.21		6.15		10.43	5.56	4.83	
Black cottonwood				1.58			8.07				
Arbutus					8.11						
Cascara	0.25			9.47		1.23		3.07	6.25	1.49	
Pin cherry			2.34								
Choke cherry					1.35						
Oak spp.										0.37	
Total %	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
% Coniferous	97.48	96.39	71.09	58.42	87.16	73.85	46.77	66.26	36.11	86.62	100.00
% Deciduous	2.52	3.61	28.91	41.58	12.84	26.15	53.23	33.74	63.89	13.38	0.00

Table 14. Percent tree composition within habitat plots by study site and tree type (coniferous vs. deciduous).

From Table 15 we can see that the majority of trees within study sites ranged between 30 and 50 cm in diameter although, again each park has a unique composition. The relative density of small diameter regenerating trees is an indication of how open the canopy is between study sites. A closer look gives us an idea of the structure of the stand at each site. Wickenden Park is distinctly an older mature hemlock stand having fewer very large diameter trees in each plot associated with an abundance of very small regenerating trees (Table 15). Sunnyside Urban Forest and Robert Burnaby

Park had relatively low regeneration. Central and Lighthouse Park had the highest abundance of veteran or legacy trees, although Central had a more even distribution of all size intervals than the other study sites. All study sites had trees in the full range of size intervals up to 100 centimeters (cm) dbh except Wickenden Park. Four did not contain trees greater than 100 cm dbh which may be an indication of more recent major disturbances. The parks with the lowest number of trees overall in habitat plots were Central Park and Sunnyside Urban Forest. Isolating trees in the larger dbh size classes (bottom of Table 15) reveals that Wickenden, Watershed and Central Parks, and Sunnyside Urban Forest, had the highest numbers of large trees per plot.

Diameter interval (cm)	Belcarra	Bowen EcoRes	Central	Green Timbers	Lighthouse	Mundy	Robert Burnaby	Sunnyside Acres	Tynehead	Watershed	Wickenden
<12	26.6	11.8	4.4	6.3	11.7	9.9	2.5	1.5	6.3	9.4	23.0
12.5-17.5	1.7	1.3	1.4	1.2	2.1	2.3	1.0	0.8	1.8	2.2	0.0
17.5-30	3.7	3.0	1.8	4.5	4.5	6.4	2.5	3.8	2.8	6.4	0.0
30-50	5.0	4.9	2.0	3.2	4.7	4.7	5.8	4.5	4.4	4.2	2.3
50-75	1.9	2.6	2.1	3.0	2.3	2.2	2.5	3.3	2.1	4.1	2.3
75-100	0.7	0.6	1.6	0.8	0.9	1.6	1.3	0.8	0.6	0.6	3.0
>100	0.1	0.1	0.9	0.0	0.7	0.0	0.0	0.1	0.1	0.0	0.3
Total	39.7	24.3	14.2	19.0	26.9	27.1	15.5	14.8	18.0	26.9	30.8
Trees >17 cm	11.4	11.3	8.3	11.5	13.1	14.8	12.0	12.5	10.0	15.3	7.8
Trees >30 cm	7.7	8.3	6.6	7.0	8.6	8.4	9.5	8.7	7.3	8.9	7.8
Trees >50 cm	2.7	3.4	4.6	3.8	3.9	3.8	3.8	4.2	2.9	4.7	5.5

Table 15. Frequency of trees per plot by diameter at breast height and study site.

The live tree data for Lighthouse Park is presented as a sample of the type of information gained from habitat plots at each study site (Table 16). Key observations include the fact that the oldest tree species are primarily Douglas–fir with some Western hemlock. The younger recruitment trees are primarily conifers and *Arbutus,* which may be site specific. The site is generally a mature coniferous forest with high structural and tree species diversity. Figure 9 displays the same information from a different visual perspective.

Lighthouse Park									
	Diameter interval (cm)								
Species	**<12**	**12.5-17.5**	**17.5-30**	**30-50**	**50-75**	**75-100**	**>100**	**Percent**	**N**
Douglas-fir	6.42	3.04	4.05	7.43	5.41	1.69	2.70	30.74	91
Western hemlock	17.91	0.34	0.00	1.69	1.01	0.00	0.00	20.95	62
Western redcedar	11.15	1.01	6.76	7.77	1.01	1.69	0.00	29.39	87
Shore pine	2.70	1.35	1.69	0.34	0.00	0.00	0.00	6.08	18
Red alder	0.00	0.00	0.00	0.34	0.34	0.00	0.00	0.68	2
Bigleaf maple	1.35	0.34	0.68	0.00	0.34	0.00	0.00	2.70	8
Arbutus	3.04	1.35	3.38	0.00	0.34	0.00	0.00	8.11	24
Choke cherry	1.01	0.34	0.00	0.00	0.00	0.00	0.00	1.35	4
Percent	43.58	7.77	16.55	17.57	8.45	3.38	2.70	100.00	
N	129	23	49	52	25	10	8		296

Table 16. Percentages of live trees in habitat plots at Lighthouse Park by size interval and species.

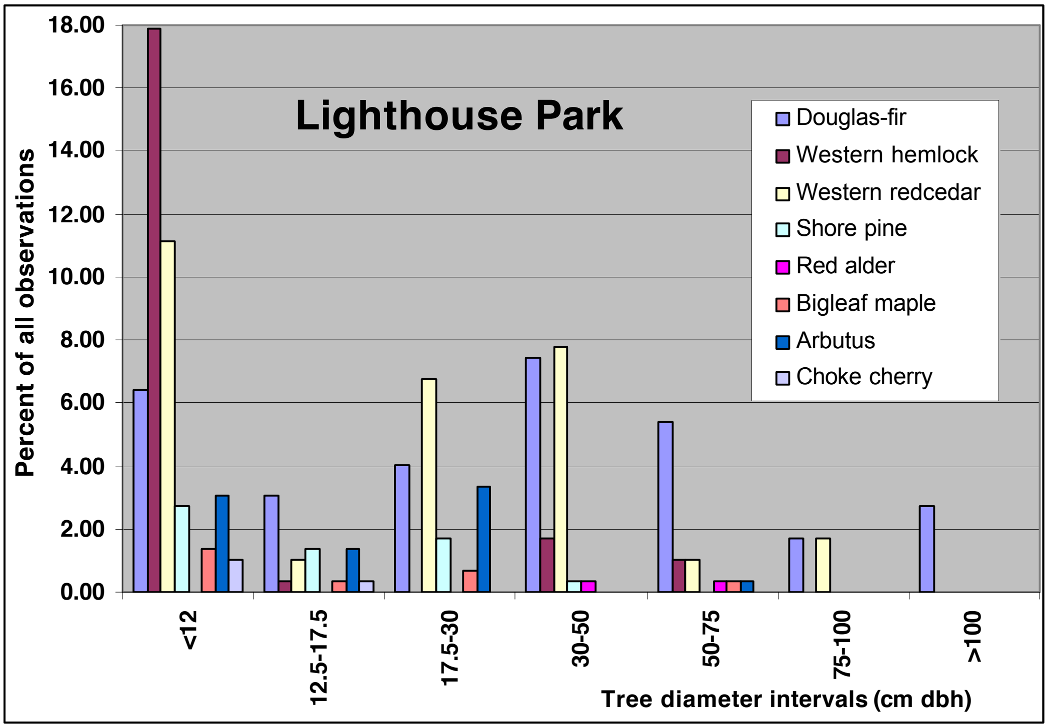
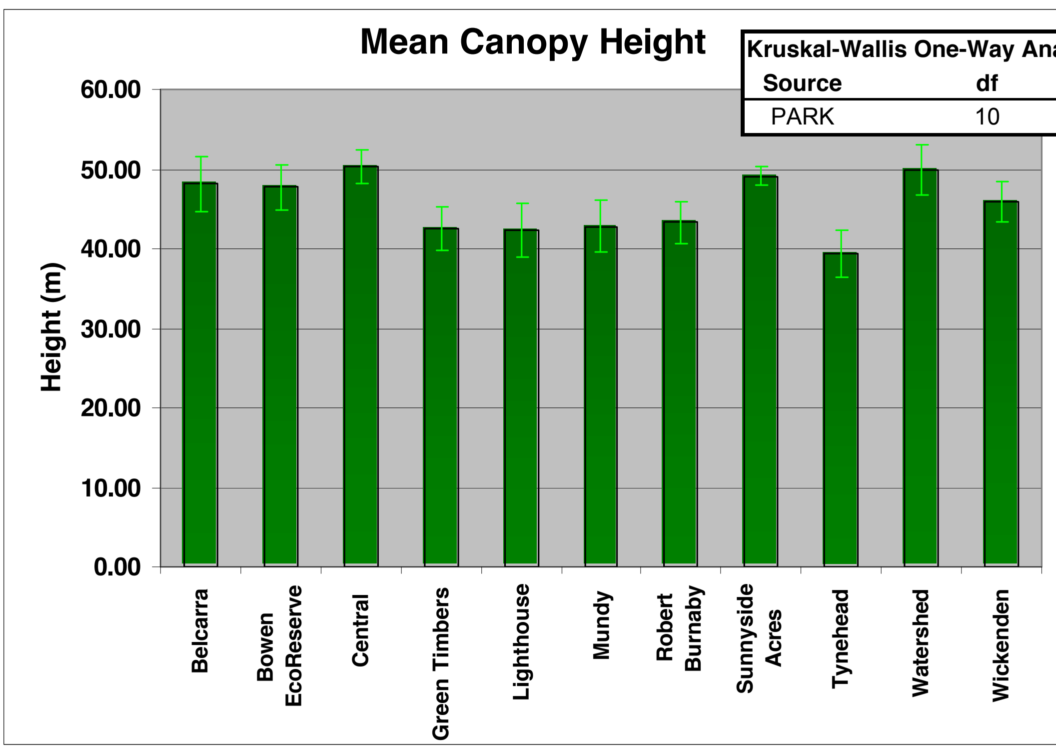


Figure 9. Live tree data from habitat plots at Lighthouse Park showing size and species composition.



Kruskal-Wallis One-Way Analysis of Variance			
Source	df	F-ratio	P
PARK	10	13.689	0.188

Figure 10. Mean tree canopy height (± SE) by study site.

There were no significant differences in mean canopy height among study sites (Figure 10). The mean of several canopy height measurements taken from each habitat plot were averaged across plots in each park which explains the relatively similar standard error around each park mean. Mean tree heights ranged from 39.43 to 50.24 m. Tynehead Park had the lowest mean tree height which is likely due to a predominance of deciduous trees. The tallest trees were within plots in Watershed and Central Parks. Future canopy data analysis will investigate the individual variation in tree height across plots and study sites.

		A0	A1	A2	A3	B1	B2	C	D
Belcarra	X	0.00	2.00	55.00	11.50	23.80	14.10	10.00	23.00
	SE	0.00	2.00	5.73	1.50	5.70	3.01	2.59	7.06
Bowen EcoReserve	X	3.13	1.88	43.13	7.00	6.25	6.88	29.63	30.88
	SE	3.13	1.88	5.26	2.01	2.55	2.67	6.09	8.21
Central	X	0.00	20.00	41.11	12.78	47.22	20.89	26.67	21.22
	SE	0.00	9.79	4.84	2.22	4.57	4.45	5.77	5.39
Green Timbers	X	0.00	2.00	45.00	11.50	39.50	26.50	24.50	9.10
	SE	0.00	2.00	3.25	3.17	4.38	2.12	2.73	1.89
Lighthouse	X	1.82	10.46	40.91	21.09	11.59	37.73	11.91	21.91
	SE	1.82	3.12	3.98	2.49	2.24	5.28	3.32	5.37
Mundy	X	0.00	7.92	48.33	21.00	39.75	40.42	14.75	18.08
	SE	0.00	3.82	4.00	2.43	7.77	5.35	3.04	2.50
Robert Burnaby	X	0.00	3.75	62.50	10.00	30.50	20.50	19.25	8.75
	SE	0.00	3.75	10.31	7.07	11.00	7.03	5.14	3.84
Sunnyside Acres	X	2.27	5.46	41.82	11.36	35.00	26.09	30.00	3.82
	SE	2.27	3.33	3.65	2.70	3.09	5.89	2.52	0.83
Tynehead	X	0.00	8.13	55.63	7.25	36.25	18.75	22.13	2.69
	SE	0.00	4.00	7.93	2.88	5.81	1.57	3.09	0.82
Watershed	X	0.00	4.00	49.50	19.20	33.00	38.50	10.60	10.60
	SE	0.00	3.06	3.98	3.40	5.88	6.41	3.25	2.62
Wickenden	X	0.00	11.25	63.75	5.00	35.00	16.25	23.75	9.25
	SE	0	7.181	14.05	5	7.36	3.75	4.27	2.175

Table 17. Mean percent cover by vegetation layer and study site, X = mean, SE = standard error. Most layers are depicted below in **Figure 11**, A0 = veteran trees surviving the last major disturbance event, A1 = tall dominant trees, A2 = main tree canopy, A3 = sub-canopy trees, B1 = tall shrubs, B2 = low shrubs, C = herb layer, D = moss, lichen, liverworts, seedlings.

Brown Creeper
(*Certhia Americana*)

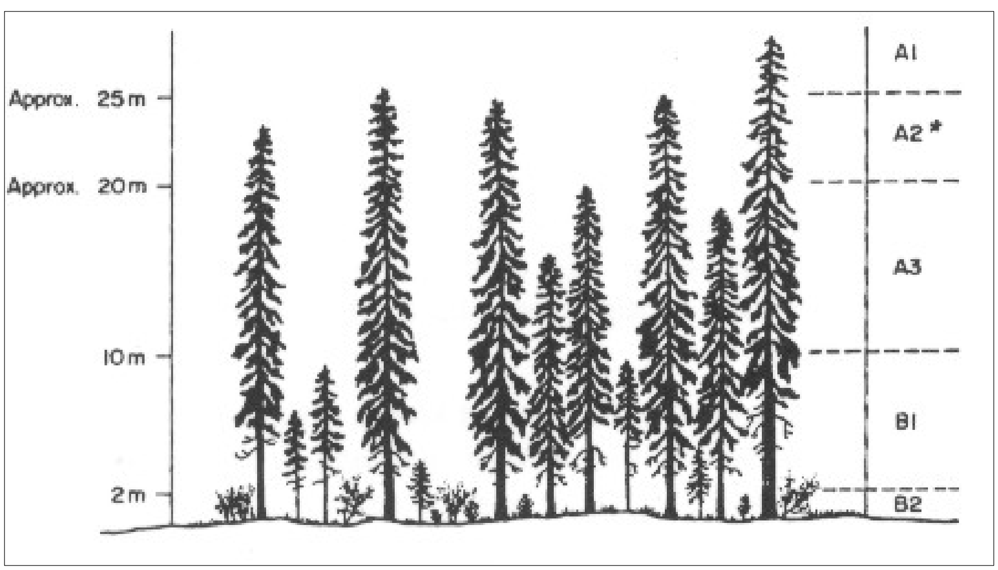


Figure 11. Stratification of forest stands, shrubs and trees into vegetation layers. *A2 = main tree canopy (RISC 2003).

The mean dominant tree canopy cover ranged from 63.75% in Wickenden Park to a more open canopy in Lighthouse Park, 40.91% (Table 17). All parks had a small percentage of A1 or taller dominant trees contributing to the main canopy although Central Park had a considerably higher proportion (20%), which may have been associated with its relatively high number of large diameter trees. Central park also had the densest tall shrub cover. Most other study sites averaged 34% tall shrub cover except two, Lighthouse Park and Ecological Reserve 48 with 11.59% and 6.25%, respectively. Low shrub cover was variable among study sites. Herb cover ranged from 10-30% among sites. Mean moss cover was highest at Ecological Reserve 48 (30.88%), very low at Tynehead Park (2.59%) and variable among other study sites.

Dead Trees

Snags were present at all plots at all study sites. Each snag observed in plots was assessed for wildlife tree class but these data have not yet been summarized. Future analyses will provide an index of potential wildlife trees at each of these study sites. It is apparent from Table 18 that snags in most study sites were predominantly coniferous, primarily Douglas-fir. Mundy, Tynehead and Central Parks were the exception with a higher proportion of deciduous snag species. Except for Lighthouse Park, which has a marine interface, the common deciduous species across all study sites were red alder and paper birch.

Species	Belcarra	Bowen EcoRes	Central	Green Timbers	Lighthouse	Mundy	Robert Burnaby	Sunnyside Acres	Tynehead	Watershed	Wickenden
Douglas-fir	50.90	80.19	30.77	57.14	32.76	11.47	0.00	77.41	0.00	58.33	0.00
Western hemlock	33.78	3.87	7.69	6.43	10.35	16.97	10.00	0.00	19.05	17.11	80.00
Western redcedar	14.41	1.45	0.00	15.71	12.07	14.68	60.00	2.59	21.43	10.09	0.00
Grand fir	0.00	0.00	0.00	0.71	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sitka Spruce	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.38	0.00	0.00
Shore pine	0.00	0.48	0.00	0.00	5.17	0.00	0.00	0.00	0.00	0.00	0.00
Red alder	0.23	13.53	38.46	6.43	6.90	29.82	10.00	12.22	30.95	1.32	20.00
Bigleaf maple	0.00	0.00	0.00	0.00	1.72	1.38	20.00	0.00	4.76	3.51	0.00
Paperbirch	0.68	0.48	19.23	13.57	0.00	25.23	0.00	7.78	21.43	9.65	0.00
Arbutus	0.00	0.00	0.00	0.00	29.31	0.00	0.00	0.00	0.00	0.00	0.00
Cascara	0.00	0.00	0.00	0.00	0.00	0.46	0.00	0.00	0.00	0.00	0.00
Pin cherry	0.00	0.00	3.85	0.00	1.72	0.00	0.00	0.00	0.00	0.00	0.00
Total %	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
N	444.00	207.00	26.00	140.00	58.00	218.00	10.00	270.00	42.00	228.00	25.00
Conif %	99.10	85.99	38.46	80.00	60.35	43.12	70.00	80.00	42.86	85.53	80.00
Decid %	0.90	14.01	61.54	20.00	39.66	56.88	30.00	20.00	57.14	14.47	20.00

Table 18. Percent snag composition by species among study sites. Because numbers of habitat plots varied among parks, N is not a useful comparison of snag density.

The general trend in snag diameter across study sites was less than 30 cm dbh, except in Robert Burnaby Park and Green Timbers Urban Forest where a large proportion of the snags had been old or veteran trees before dying (Table 19). All parks had snags present in all dbh intervals. Future analyses will assess numbers, sizes and species of snags available per hectare to assess whether the habitat requirements for particular cavity nesters are being met.

DBH (cm)	Belcarra	Bowen EcoRes	Central	Green Timbers	Lighthouse	Mundy	Robert Burnaby	Sunnyside Acres	Tynehead	Watershed	Wickenden
<12	51.80	30.44	19.23	12.86	39.66	7.80	30.00	18.15	21.43	29.83	0.00
12.5-17.5	14.41	23.67	15.39	17.14	12.07	23.39	10.00	15.56	19.05	25.44	8.00
17.5-30	14.64	28.50	30.77	22.14	22.41	39.91	0.00	33.70	19.05	26.32	40.00
30-50	4.96	14.01	15.39	7.86	8.62	14.68	10.00	11.85	14.29	5.26	24.00
50-75	3.60	1.45	7.69	5.00	6.90	2.29	0.00	4.07	9.52	4.83	8.00
75-100	4.28	0.97	11.54	9.29	5.17	3.21	40.00	8.52	4.76	1.75	12.00
>100	6.31	0.97	0.00	25.71	5.17	8.72	10.00	8.15	11.91	6.58	8.00
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Table 19. Percent of snags in 7 diameter intervals (cm dbh) among study sites.

Snag diversity in Mundy Park is presented as a sample of the type of information that is available from habitat plots for all parks (Table 20). Snags are primarily red alder and paper birch under 30 cm in diameter. The largest 26 snags (> 75 cm dbh) are primarily Douglas-fir. There were 63 snags greater than 30 cm in diameter in the twelve 0.2 hectare habitat plots yielding an average of 26.25 snags/ha. This is below the requirements recommended for management of habitat for pileated woodpeckers (Bull and Jackson 1996, Lewis and Rodrick 2004).

Mundy Park								
	DBH Interval							
Species	**<12**	**12.5-17.5**	**17.5-30**	**30-50**	**50-75**	**75-100**	**>100**	**N**
Douglas-fir	0	3	0	2	2	5	13	25
Western hemlock	7	12	15	1	1	1	0	37
Western redcedar	9	8	4	3	1	1	6	32
Red alder	0	12	41	12	0	0	0	65
Bigleaf maple	0	0	3	0	0	0	0	3
Paper birch	0	16	24	14	1	0	0	55
Cascara	1	0	0	0	0	0	0	1
N	17	51	87	32	5	7	19	218

Table 20. The frequency of snag species by dbh interval in Mundy Park.

Both mean largest tree and mean largest snag differed significantly between study sites (P = 0.001, P = 0.036 respectively). There appeared to be no relationship between largest tree and largest snag within study sites and varied considerably among habitat plots (Figure 12). The largest tree within habitat plots over all study sites was a Douglas-fir tree, 179.0 cm dbh, in Lighthouse Park. Lighthouse, Central and Wickenden Parks had the highest mean dbh of large trees among sites (106.31 cm, 101.39 cm and 99.28 cm respectively). The largest snag overall was a Douglas-fir, 170 cm dbh, in Mundy Park. Belcarra had the largest mean snag dbh among sites (91.86 cm).

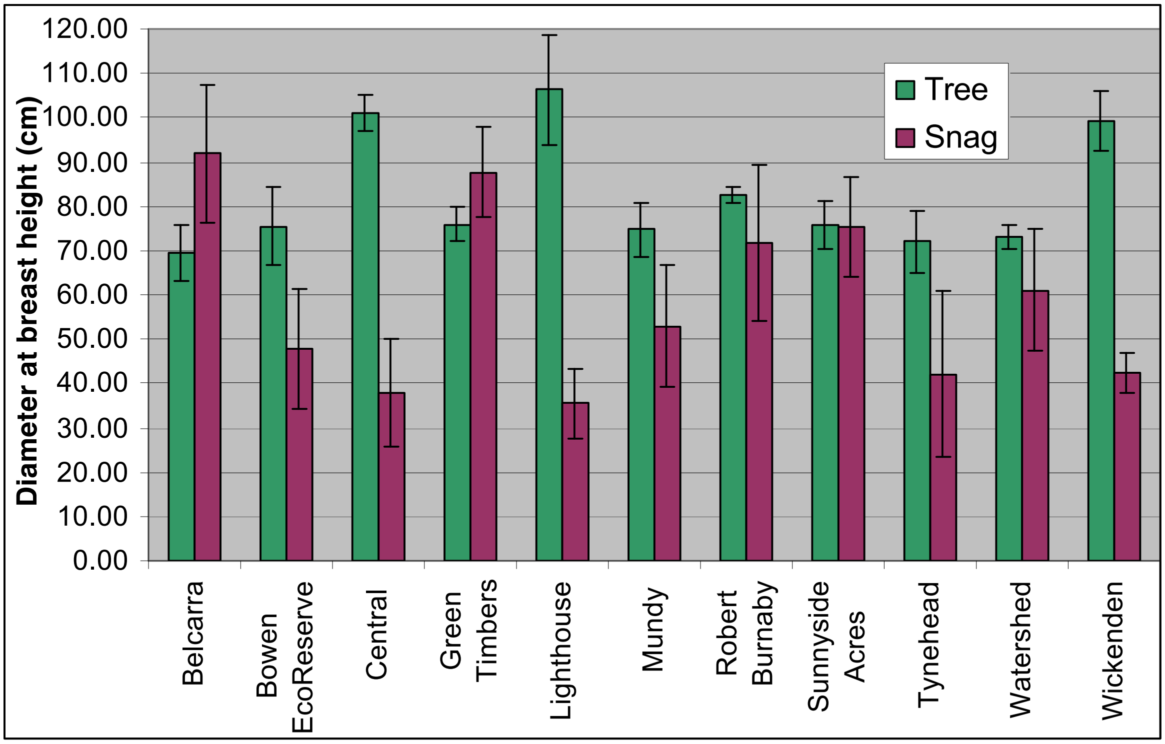


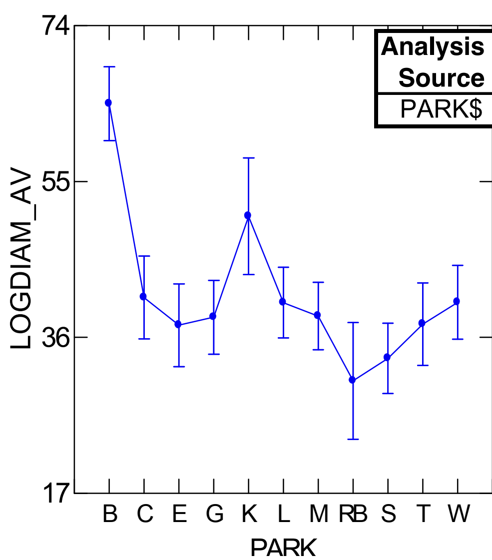
Figure 12. Mean largest tree and snag (± SE) in each habitat plot compared among study sites.

Analysis of Variance - Largest Tree			
Source	df	F-ratio	P
PARK$	10	3.472	0.001

Analysis of Variance - Largest Snag			
Source	df	F-ratio	P
PARK$	10	2.079	0.036

Logs

Mean largest log diameter ranged from 30.70 cm to 40.86 cm for most study sites (Table 21). Belcarra Park had the largest mean log sizes (Figure 13), averaging 64.47 cm, followed by Wickenden Park at 50.75 cm. Analysis of variance indicated that log diameters were significantly different among parks (F = 3.586, df = 10, 85, P = 0.001) but post-hoc tests showed that no parks differed from one another except Belcarra Park which had larger logs than all other study sites except Wickenden Park.



Analysis of Variance - Largest Log			
Source	df	F-ratio	P
PARK$	10	3.586	0.001

Rufous Hummingbird
(*Selasphorus rufus*)

Figure 13. Mean largest log diameter in plot quarters across study sites.

Largest Log in Each Plot				
			(cm)	(m)
Park		Log Count	Log Diameter	Log Length
Lighthouse	Mean	3.00	40.24	8.87
	Std. Error	0.30	5.57	0.91
Wickenden	Mean	4.00	50.75	9.38
	Std. Error	0.00	8.36	1.43
Central	Mean	2.56	40.86	9.08
	Std. Error	0.44	6.23	3.50
Mundy	Mean	3.67	38.59	12.06
	Std. Error	0.26	3.41	1.88
Watershed	Mean	3.70	40.28	10.39
	Std. Error	0.15	2.69	1.18
Tynehead	Mean	2.13	37.61	13.48
	Std. Error	0.35	3.63	2.62
Sunnyside	Mean	3.91	33.46	11.73
	Std. Error	0.09	3.15	1.81
Robert Burnaby	Mean	3.25	30.70	11.95
	Std. Error	0.48	5.70	0.43
Belcarra	Mean	4.00	64.47	14.11
	Std. Error	0.00	7.44	1.13
Green Timbers	Mean	3.70	38.46	15.45
	Std. Error	0.21	2.81	1.85
Ecoreserve	Mean	4.00	37.49	16.06
	Std. Error	0.00	3.56	2.60

Table 21. Mean diameter and length of largest logs from each plot quarter.
Where log count is less than 4 there were habitat plots without logs in = 1 plot quarter.

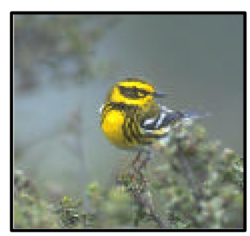
Plant Species Diversity

Over all study sites, 121 woody and herbaceous plant species were identified (Table 22). Additional moss, liverwort and fungus species (26 species) were also identified but these plant groups were not surveyed intensively and so will not be included in future plant species diversity indices.

Plant Group	No. Species
Trees	16
Shrub	27
Herb	65
Grass, Reeds and Sedges	5
Exotics	8
	121

Table 22. Species richness observed in habitat plots over all study sites not including moss, liverwort and fungus groups.

Black-throated gray warbler (*Dendroica nigrescens*)



Townsend's warbler (*Dendroica townsendi*)

In approximately 50% of habitat plots across study sites, Vine maple (*Acer circinatum)* was the most abundant shrub and either salmonberry (*Rubus spectabilis*) or red huckleberry (V*accinium parvifolium*) were the second most common shrub species (Table 23). In only 2.06% of all plots, no shrub species were dominant. In 28.86% of plots there was not a Dominant 2 or 3 shrub species, which indicates that these plots were overwhelmingly dominated by category Dominant 1 shrubs. Of the total number of shrub species recorded, 5 were most abundant among plots. Future analyses will evaluate potential shrub species associations among the 5 dominance categories.

	Common Name	Latin Name	DOM 1	DOM 2	DOM 3
	Baldhip	*Rosa gymnocarpa*	0.00	0.00	1.03
	Beaked Hazelnut	***Corylus cornuta***	0.00	5.15	9.28
	Black Huckleberry	*Vaccinium membranaceum*	0.00	1.03	0.00
	Devils Club	*Oplopanax horridus*	1.03	0.00	1.03
	False Azalea	*Menziesia ferruginea*	1.03	1.03	1.03
Exotic	Himalayan Blackberry	*Rubus discolor*	1.03	0.00	0.00
Exotic	Holly	*Ilex opaca*	0.00	1.03	1.03
	Indian Plum	*Oemleria cerasiformis*	0.00	0.00	2.06
	Ocean Spray	*Holodiscus discolor*	0.00	0.00	2.06
	Oregon Grape	*Mahonia nervosa*	1.03	1.03	2.06
	Pacific Rhododendron	*Rhododendron macrophyllum*	0.00	0.00	1.03
	Red Elderberry	*Sambucus racemosa*	0.00	1.03	1.03
	Red Huckleberry	***Vaccinium parvifolium***	13.40	25.77	21.65
	Salal	***Gaultheria shallon***	16.49	10.31	9.28
	Salmonberry	***Rubus spectabilis***	12.37	32.99	6.19
	Saskatoon Berry	*Amelanchier alnifolia*	1.03	2.06	0.00
	Trailing Blackberry	***Rubus ursinus***	0.00	3.09	13.40
	Vine Maple	***Acer circinatum***	50.52	10.31	3.09
	Tree regeneration	*n/a*	0.00	0.00	1.03
	***No shrubs present**	**n/a**	2.06	5.15	23.71
			100	100	100

Rank	
1	(orange)
2	(green)
3	(purple)
4	(blue)
5	(yellow)

Table 23. The percentage of plots, over all study sites combined, in which each shrub species was the first, second and third most abundant and recorded as Dominant 1, 2 and 3, respectively. Species were assigned a rank of 1 to 5 based on declining percentages within each dominance category.

Belcarra had the highest diversity in shrub species (Table 24). Vine maple dominated most study sites, and especially appeared more dominant in parks where human disturbance was highest, i.e. Central Park and Green Timbers Urban Forest. Notably, vine maple was not dominant in any plots in Ecological Reserve 48 or Lighthouse Park which instead were dominated by red huckleberry and salal, respectively.

	Species	Belcarra	Eco Reserve	Central	Green Timbers	Lighthouse	Mundy	Robert Burnaby	Sunnyside Acres	Tynehead	Watershed	Wickenden
	Oplopanax horridus	10	0	0	0	0	0	0	0	0	0	0
	Menziesia ferruginea	10	0	0	0	0	0	0	0	0	0	0
Exotic	*Rubus discolor*	0	0	0	0	0	0	0	0	13	0	0
	*No shrubs present	10	13	0	0	0	0	0	0	0	0	0
	Mahonia nervosa	0	13	0	0	0	0	0	0	0	0	0
	Vaccinium parvifolium	10	50	0	0	18	8	0	9	0	10	75
	Amelanchier alnifolia	0	0	0	0	9	0	0	0	0	0	0
	Gaultheria shallon	20	25	0	0	64	17	0	9	0	20	0
	Rubus spectabilis	20	0	0	10	9	33	25	0	38	0	0
	Acer circinatum	20	0	100	90	0	42	75	82	50	70	25
	Total Percent	100	100	100	100	100	100	100	100	100	100	100
	No. Plots	10	8	9	10	11	12	4	11	8	10	4

Table 24. Percent of plots in which each shrub species was classified as Dominant 1.

Species-Habitat Associations

Various univariate analyses were conducted to explore relationships of the 7 most common focal species to a selection of habitat variables (Table 25). This process was exploratory in nature and gave both some expected and unexpected results for each species. Values in each of the cells in Table 25 represent the percent of variation in mean bird abundance that can be explained by the habitat parameter on the left. A significant number of additional habitat variables are available yet to analyze including those for which the data are not numeric but descriptive in nature such as dominant shrub, tree or ground cover species, or mesoslope position. The strongest relationships in this first analysis were the positive effects of elevation and slope on both warbler species. Black-throated gray warbler abundance appeared negatively correlated with vegetation 2-10 m in height. Spotted towhee abundance appeared negatively correlated with elevation. Future multivariate analyses are likely to result in stronger relationships which will indicate important habitat associations for these species in the study sites visited.

	Indicator Species						
Plot Habitat Variables	**BGWA**	**BRCR**	**PIWO**	**RBNU**	**RUHU**	**SPTO**	**TOWA**
Total Snag Count	ns	ns	0.074*	ns	ns	0.101	ns
Mean Number Conifer Shrubs	ns	ns	ns	ns	ns	ns	ns
Mean Number Deciduous Shrubs	0.182	ns	ns	0.041	ns	0.064	ns
Mean % Canopy Cover Transformed	0.041	ns	ns	ns	ns	ns	ns
Mean % Conifer Cover Transformed	0.112	ns	ns	ns	ns	ns	ns
Mean Ground Hits of Cover	ns	ns	ns	ns	ns	ns	ns
Mean Canopy Height	ns	ns	ns	0.059	ns	ns	0.055
Total Live Tree Basal Area	ns	0.087	0.059	ns	ns	ns	ns
Total Live Tree Count	ns	ns	ns	ns	ns	0.043	ns
% Conifer Tree Transformed	0.115	ns	ns	ns	ns	0.080	ns
% Deciduous Tree Transformed	0.115	ns	ns	ns	ns	0.080	ns
% Cover A0 Layer Transformed	ns	ns	ns	ns	ns	ns	ns
% Cover A1 Layer Transformed	ns	ns	ns	ns	ns	0.043	ns
% Cover A2 Layer Transformed	ns	ns	ns	ns	ns	ns	ns
% Cover A3 Layer Transformed	ns	ns	0.125	0.051	ns	ns	ns
% Cover B1 Layer Transformed	0.354	ns	ns	ns	0.067	0.094	0.134
% Cover B2 Layer Transformed	0.050	ns	ns	0.098	0.044	0.091	ns
% Cover C Layer Transformed	ns	ns	ns	ns	0.043	ns	ns
% Cover D Layer Transformed	0.120	ns	ns	ns	ns	ns	0.050
Elevation	0.419	0.094	ns	ns	ns	0.202	0.364
Slope	0.206	ns	ns	ns	ns	ns	ns
Aspect	ns	ns	ns	0.052	0.048	ns	ns

RED indicates a negative regression line; **BLACK** indicates a positive regression line
* Deciduous snag count only
Numbers in cells are r^2 values
Transformed values are converted to approximate a normal distribution using arcsine square root

Table 25. Relationships between a selection of habitat variables and the 7 most abundant focal species. The numerical value in each cell is the Pearson correlation coefficient of each statistically significant linear regression of the focal bird species mean abundance in each plot on the corresponding habitat variable. ns = non-significant regression, BGWA = black-throated gray warbler, BRCR = brown creeper, PIWO = pileated woodpecker, RBNU = red-breasted nuthatch, RUHU = rufous hummingbird, SPTO = spotted towhee, TOWA = Townsend's warbler

In an exploratory fashion, I investigated a correlation between mean total basal area of plots in each study site and avian diversity. Forest plots with larger mean basal area are likely to be older stands. The expected relationship in older mature forests is a positive linear or curvilinear relationship since more open canopies usually result in higher structural diversity. This expectation is reflected in the positive regression displayed in Figure 14 in which basal area explains 26% of the variation in species richness ($r^2 = 0.263$, t = 3.71, P = 0.031). The same relationship is apparent in Figure 15 where basal area is positively correlated with rarified Shannon-Wiener Index ($r^2 = 0.233$, t = 2.01, P = 0.38) and 23% of the variation in species diversity is explained by mean basal area of plots in study sites.

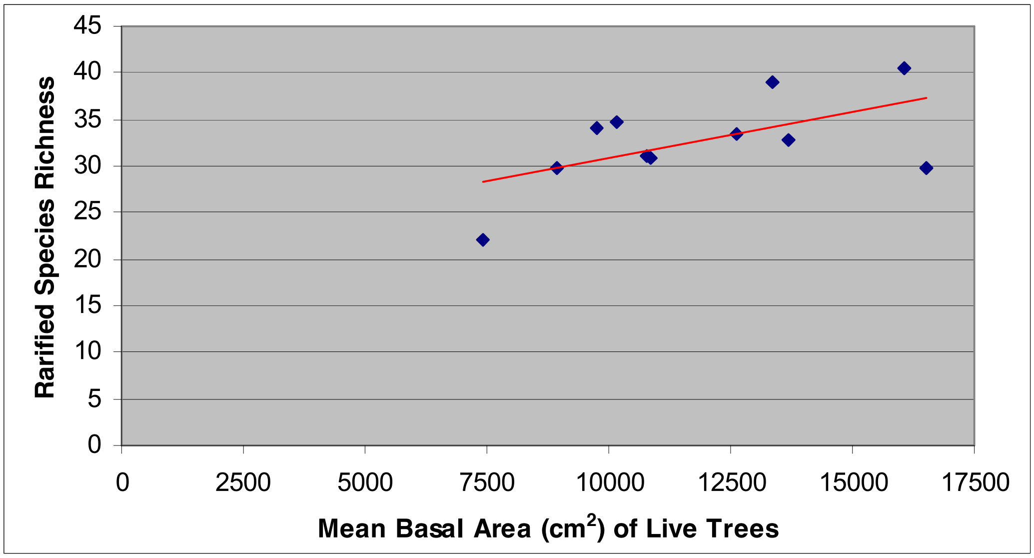


Figure 14. Mean basal area of live trees per study site in relation to rarified species richness (n = 238).

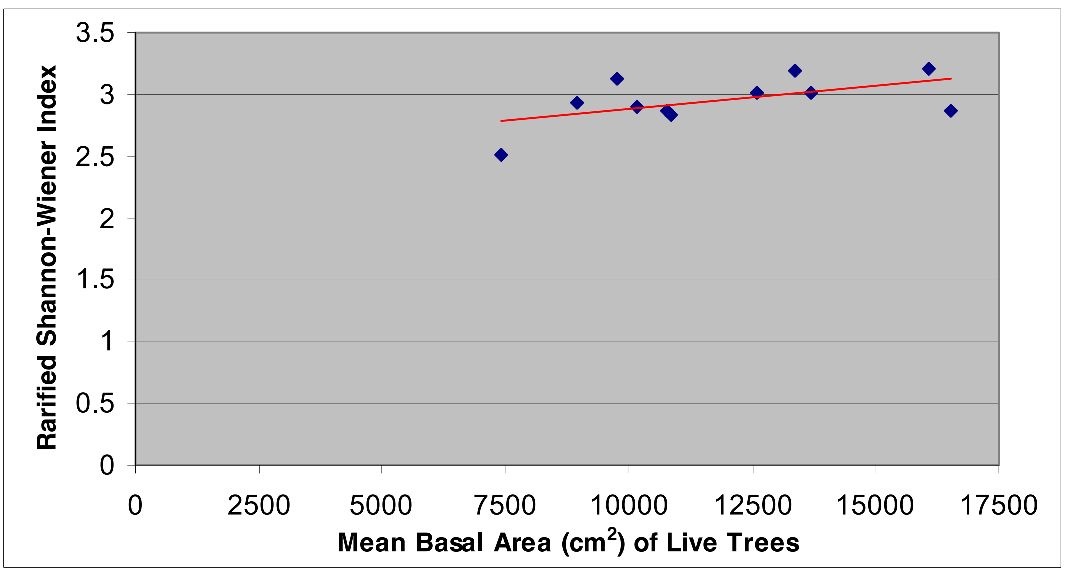


Figure 15. Mean total basal area of plots per study site in relation to rarified diversity index (n = 238).

Disturbance Factors

Mean number of people observed during bird point surveys differed significantly among parks (Figure 16). Bonferroni post-hoc pairwise comparisons indicated that Central Park had significantly more people than all other parks (P<= largest p value). In fact, considering that surveys were 10 minutes in duration, the above results indicate approximately one person per minute.

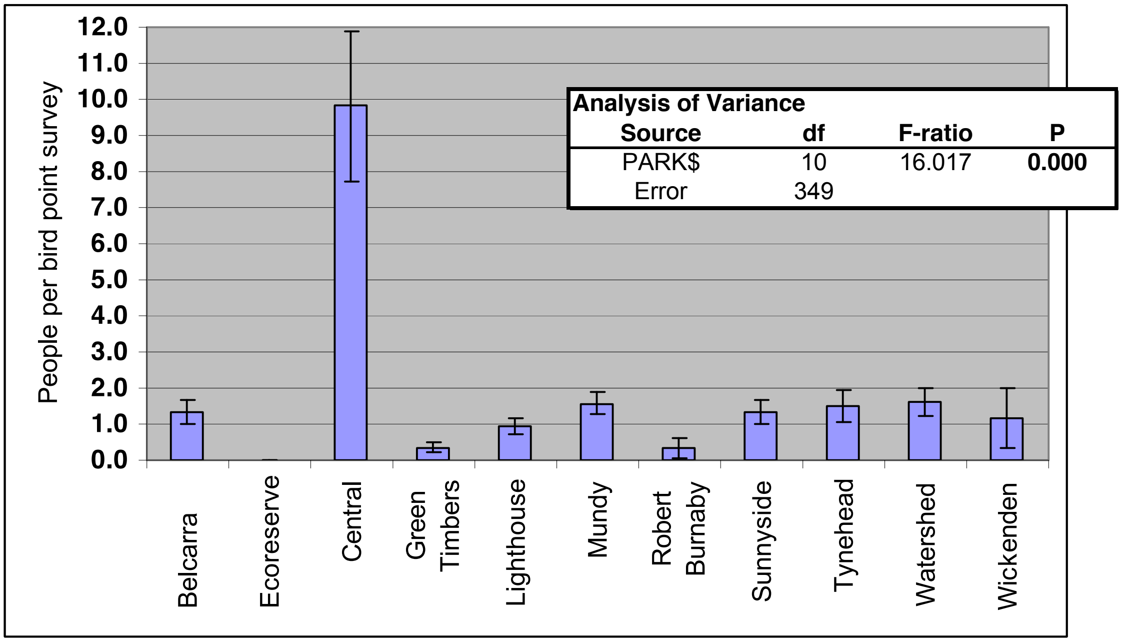


Figure 16. Mean number of people observed per bird point survey (± SE) among study sites.

Mean number of planes observed during bird point surveys did not differ significantly among parks. The range of observation was approximately one plane every 30 minutes in Belcarra Park to almost one plane per minute in Lighthouse Park (Figure 17). This amounts to approximately 1 plane every 20 minutes over all parks

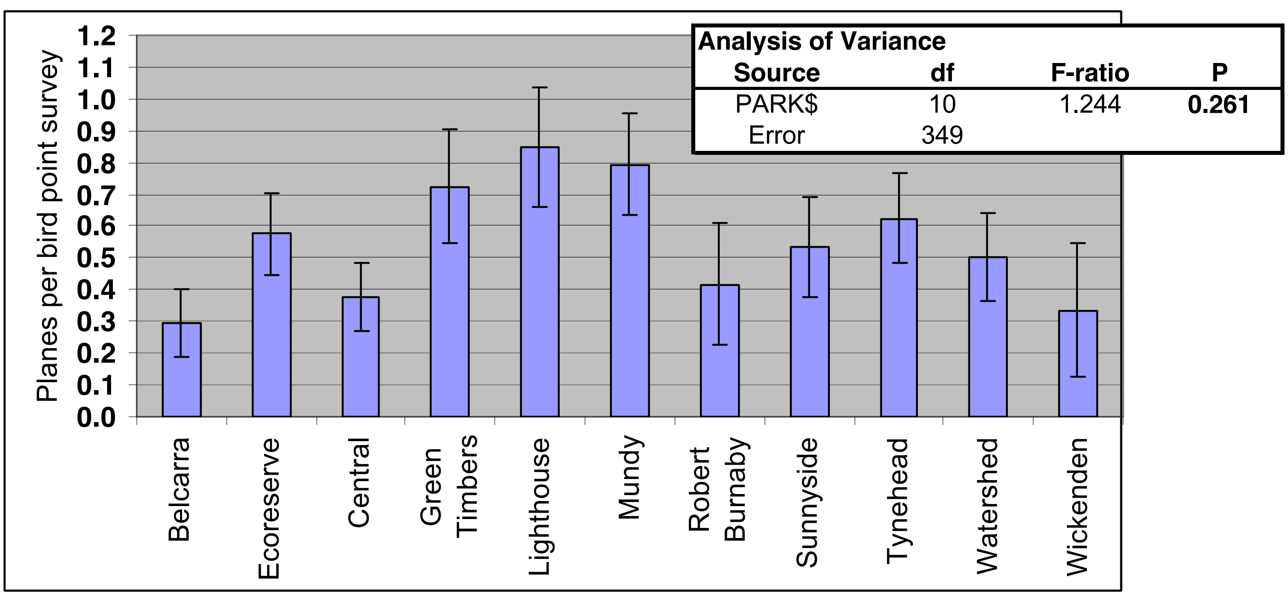


Figure 17. Mean number of planes observed per bird point survey (± SE) among study sites.

GIS analysis

Mapping of field data and the spatial analysis of various disturbance factors affecting each forested site, such as road and housing densities, connectedness and fragmentation, have yet to be completed.

DISCUSSION

Avian Species Abundance

An average of 40 species was observed in each study site. Of the 69 species observed across all study sites, 22 species individually comprised from 1 to 12% of observations, and cumulatively comprised 89% of all observations (Table 3a and 5, and Appendix 1). The remaining 47 species individually comprised less than 1% of all observations.

The three most abundant species were winter wren, American robin and Swainson's thrush (*Catharus ustulatus*) and were not focal species. Winter wrens are potentially most abundant due to life history traits such as small territory size (Waterhouse and Harestad 2002). American robins are well adapted generalists and are found in a wide range of habitats including disturbed areas (Campbell et al. 1990). The Swainson's thrush inhabits a range of forest types but depends on dense fruiting understory for forage and nesting sites (Campbell et al. 1990). Such habitats are common in rural and suburban areas. Spotted towhees had the highest abundance of all 9 focal species and were the only focal species to comprise more than 5% of observations. In fact, only 5 of the selected focal species (spotted towhee, brown creeper, Townsend's warbler, red-breasted nuthatch and black-throated gray warbler) comprised more than 1% of observations (Figures 3a and 3b). 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 2002). This is supported by the fact that these warblers were most abundant in Ecological Reserve 48 on Bowen Island, a relatively pristine forest and the largest of the 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. The relative abundance of brown creepers and red-breasted nuthatches may indicate the extent of older conifer communities with healthy arthropod biomasses (Adams and Morrison 1993, Weikel and Hayes 1999).

From the perspective of efficiency, the rarer a species is the more effort it will take to collect data regarding its distribution and abundance and, therefore, to use it for monitoring habitat. The smaller the sample size of data, the less statistical power can be achieved to detect any effect, e.g., population trend, difference between treatment groups, etc. In the extreme case, one of the focal species, the pileated woodpecker, has a large home range size resulting in infrequent and potentially sporadic observations. In this study, pileated woodpeckers comprised only 0.37% of observations across all study sites (Table 3b). The probability of detection is inversely related to home range for a 10-minute survey interval and influences the chance of any bird being observed within 100 meters of a bird point. There are considerably more detections of pileated woodpeckers in an additional data set of my observations at distances greater than 100 meters from the bird points, however, when these data are amended to the current analyses the overall results do not increase the detection level above 1% of all observations. This might suggest 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 behavior might differ in these urban/suburban environments. An alternate survey method may be appropriate for future studies, such as line transects used to detect foraging, nest and roost excavations, and conduct visual and auditory observations (Harestad, pers. comm.).

The data collected from this study demonstrate the potential economic impediments to collecting a sufficiently robust data set for each of the focal species. Lee and Rudd (2002) list a set of nine criteria by which indicator species were selected, one of which is easy, cost-effective monitoring (Criteria 9, Table 3.1). However, these indicator species were not chosen only on the basis of abundance, but also because they are dependent on and can represent specific habitats and, therefore, 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. Power analyses are required to look at the efficiency and effectiveness of using these focal species as indicators for monitoring.

These urban/suburban study sites were not so disturbed that their avian and plant communities had a significant component of exotic species, which suggests a representation of relatively intact mature forest. However, there are ways that indigenous, as well as exotic species, can indicate extents of disturbance. For example, Central Park had a much higher percentage of Northwestern crows than other study sites. This bird is one of many synanthropic species who take advantage of new anthropogenic habitat, supplemental food and nest sites often achieving unusually high abundance and decreasing community evenness in urban areas (Marzluff 2001, Donnelly 2002).

Avian Species Diversity

The higher 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, in comparison to the other study sites. A U-shaped functional relationship exists between species richness and the stages of forest development (Wells et al. 1998, Franklin et al. 2002) (Figure 18). From the habitat information I collected, I believe the study sites in this project fell on the far end of the curve in the segment represented by the red line in Figure 18, where species richness increases toward the slightly lower maximum associated with late seral forests.

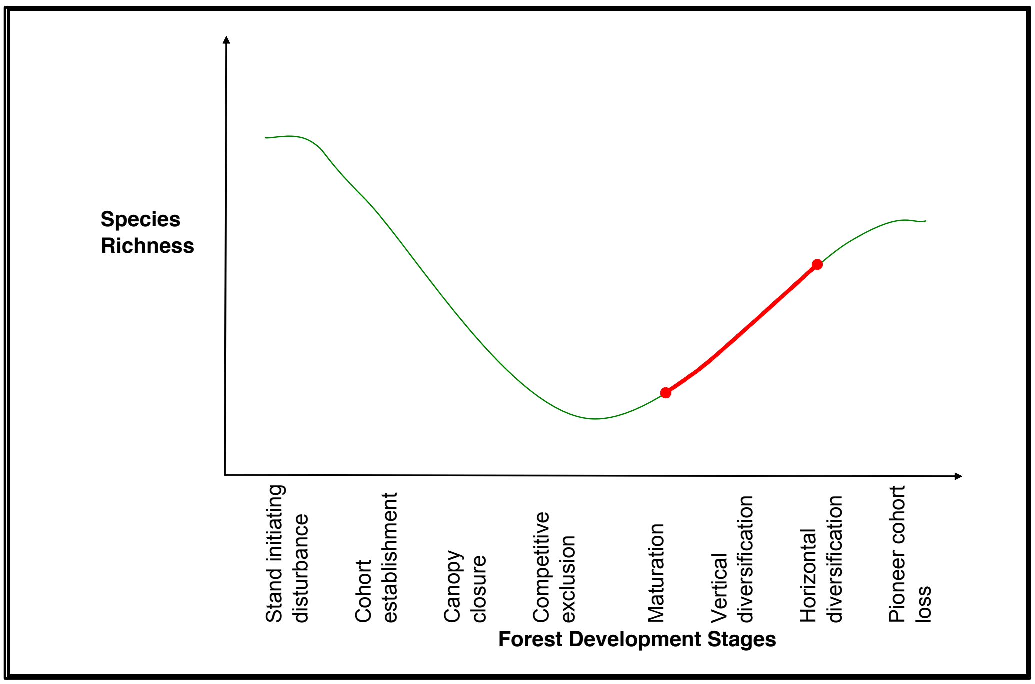


Figure 18. Species richness across forest development stages from stand initiation to old growth (Wells et al. 1998, Franklin et al 2002).

Ecological Reserve 48 on Bowen Island is a relatively large forest which has never been logged or otherwise anthropogenically disturbed and is nominally the oldest stand of all the study sites. By the above reasoning it normally would be expected to have high species richness; however, it is a different type of successional forest with a diverse topography including exposed rock bluffs and sheltered gullies. Exposed patches of forest are often subject to natural disturbances such as wind throw which may result in alteration of soil conditions, less understory vegetation and multi-aged stands (Nowacki and Kramer 1998). Is so, though not disturbed by humans, the reserve may not be functionally as old as it appears to be. It has the most open understory and extensive moss cover of all other parks (Table 17). It also averages 400 meters in elevation, more than 200 meters higher than the next highest site, Mundy Park. These factors combined may explain the lower species richness and diversity of this site. In fact, Belcarra Park which has similar topography in places to that of the reserve, also had relatively low species richness.

Tynehead is primarily a deciduous forest (64% of trees) which naturally would have more open canopy than sites dominated by coniferous trees. In addition, it has a large riparian component. For both of these reasons, I expected it to have higher species richness than other study sites which are primarily coniferous. However, its species richness was less than the average among all sites. Two factors may contribute to its lower diversity. First it had the third highest percentage of main canopy cover (Table 17). Second, it had the highest density of Himalayan blackberry, an exotic species (Table 24) which, although providing food and shelter to a wide range of species, vigorously competes with a diversity of other resident plant species creating homogeneous environments. It is also often associated with other exotic species (USDA 2004).

The implication of the species richness curves (Figure 3) is that differences in diversity can be detected after approximately 300 observations at each site. It is unlikely that another field season would change this result since there is no obvious mechanism that would significantly change species richness at these study sites outside of significant natural or anthropogenic disturbances, or climatic change. Plans for future analysis include modeling the maximum species richness for each study site which, in turn, will allow one to estimate species richness based on any number of observations exceeding a minimum determined by the model. The confidence intervals around the maximum species richness estimates will decrease as the number of observations increase.

Activity of Selected Focal Species

In more natural and undisturbed forests, pileated woodpeckers have large home ranges up to 1,000 hectares (Bull and Jackson 1995, Aubry and Raley 2002, Lewis and Rodrick 2004). It is unclear exactly which specific habitat variables in these urban systems may significantly influence nesting or foraging behaviour, and territory size in relation to habitat quality or extent of fragmentation. For example, Lighthouse Park contained an active nest in a red alder snag where the diameter at nest height was unusually small. In this study, although pileated woodpeckers were seen at all but one study site throughout the full field season, these observations usually did not occur within the 100-meter radius dictated by the bird point survey methodology. Pileated woodpecker observations often occurred within the study sites at distances greater than 100 meters from the bird points, after bird point surveys were completed (1100 h), outside of study sites coming and going from park boundaries and while conducting habitat assessments later in the season during juvenile dispersal. Additional analyses that include these observations might better reveal pileated woodpecker activity. For example, connectivity between suitable forest sites may strongly influence pileated habitat use; a case in point is Central Park. Although it is surrounded by intensive urban development and showed very low pileated woodpecker activity during bird point intervals, pileated woodpeckers were observed on most survey days. After following repeated flight paths outside the park boundary towards Deer Lake Park, I found an active nest near an entry point to that park. The lack of pileated woodpecker observations at Belcarra and Wickenden Parks may also have been a reflection of the availability of more suitable forest patches in proximity to these sites. Green Timbers Urban Forest is one of the more disturbed study sites (dense trail system, internal impervious surfaces, high nearby housing density, resident homeless people within the study site, pedestrian traffic and refuse) which potentially accounts for the lack of observations there. As expected, activity levels appear to be strongly correlated with breeding sites since nests were found in 3 of the 4 parks with the highest activity levels, Lighthouse Park, Mundy Park and Sunnyside Urban Forest. Intensive transect surveys for visual and vocal detections of pileated woodpeckers, over a broader range of daylight hours, at all study sites, would likely result in a more comprehensive and accurate evaluation of habitat use by this species.

Spotted towhee breeding habitat is characterized by dense shrub growth, riparian thickets, and shrubby seral stages of forest development; they are also well adapted to urban disturbance and frequently use backyard habitat for breeding and foraging (Greenlaw 1996, Lee and Rudd 2002, Lewis and Rodrick 2004). My preliminary analyses corroborate this. For example, spotted towhees were most common in Central Park, which I suggest is the most urban and the most human-disturbed of the study sites (dense trail system, close proximity to impervious surfaces and dense housing, resident homeless people within the study site, human use). They also were absent or nearly so from the two control sites, Belcarra Park and Ecological Reserve 48. Towhee abundance likely reflects their affinity for edges and shrubby habitat in these anthropogenically altered urban and suburban areas where shrub density and edge areas tend to be higher than in more natural stands. The control sites have lower levels of disturbance, less shrub cover and less edge effect. Therefore, in essence, spotted towhee abundance may be useful as an inverse indicator of mature forest habitat quality.

Brown creepers may 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. They 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 for foraging. In coastal forests of western North America, their abundance is correlated with the abundance of Douglas-fir trees over 100 cm dbh, and their foraging activity is correlated with the abundance of live trees over 30 cm dbh with deeply furrowed bark (Adams and Morrison 1993, Hejl et al. 2002). However, surprisingly, my analyses showed little correlation between the abundance of live or dead trees of any size class(es) of either deciduous or coniferous trees and mean brown creeper abundance within individual bird survey plots. The only significant result was that their activity was lowest in Tynehead Park, as expected, because of its high percentage of deciduous trees and, therefore, presumably a lower abundance of arthropods. The lack of relationship between brown creeper activity and tree dbh may indicate that arthropod and spider abundances are not significantly different between large and small trees in the sites involved in this study which contrasts with previous studies conducted in other areas. Or perhaps this reflects differences in arthropod abundance in disturbed versus undisturbed habitat. There was also no apparent relationship between brown creeper abundance and canopy cover. Further and more detailed (e.g. multivariate) investigations of brown creeper activity in relation to habitat parameters are necessary to determine if their abundance is correlated with any habitat characteristics in the sites I studied.

Red-breasted Nuthatches prefer mature and diverse stands of coniferous forest with high canopies and large trees and snags greater than 30 cm dbh (Adams and Morrison 1993, Ghalambor and Martin 1999). My data substantiate this, as nuthatch activity was highest in Lighthouse and Wickenden Parks, which are the oldest forest stands, and have among the highest percentage of large and 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.

Analyses of the activity of other relevant focal species have not yet been conducted, but will be presented in the final report. Activity of any of the focal species is directly related to the availability of suitable habitat. The habitat issues to consider in assessing each of the focal species are not explicit from the report by Lee and Rudd (2002), i.e. specific forest characteristics and disturbance factors related to species habitat requirements. Therefore, based on an in-depth literature review, I will also supply more detailed habitat requirements for these focal species.

Physical and Biological Habitat Parameters

As originally proposed, 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) and very dry maritime (CWHxm1) biogeoclimatic subzones (Meidinger and Pojar 1991) with minimal exotic invasion. 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. In fact 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) which allows regeneration of understory shrubs and trees. This was evident from the high variation of shrub, forb and moss cover among sites. Snags were relatively small in diameter and represented a mix of coniferous and deciduous species. Logs, which are important for providing structural diversity, cover, food and substrate on the forest floor, were generally large in diameter. Vine maple is a dominant understory shrub of coastal forests from B.C. to California and persists through stand development stages principally due to its shade tolerance and clonal reproduction but also by allelopathic inhibition of other species. It plays an important role in nutrient recycling, has a high nutritional value as forage for a range of taxa and is a unique structural and functional component of these stands (Saunders et al. in preparation). This was corroborated by its prevalence in these study sites with the exception of Lighthouse Park and Ecological Reserve 48, which may suggest an incompatibility with marine environments as vine maple prefers moister sites than are typical at these locations.

Overall, these study sites provided an environment with high species and structural diversity from which to evaluate use by the selected avian focal species. There may be several ways to arrive at a definition of 'habitat quality'; for example, a review of similar forest habitat variables at more pristine sites in the same biogeoclimatic zone, or assessing critical habitat needs for each or a group of focal species. The extent to which these study sites may or may not be high quality environments for the selected focal species is yet to be investigated (Meidinger and Pojar 1991, Pojar and McKinnon 1994, Maraj 1999, Savard et al. 2000, Donnelly 2002, Ransome 2003).

Species-Habitat Associations

These particular analyses are very important to the objectives of this research because we can draw relationships between abundance of the selected focal species and specific parameters indicative of habitat quality. There are many ways in which these relationships can be assessed; the analyses presented here are very preliminary since most future work will be focused on this particular aspect of the project results.

Table 25 summarizes the results of some preliminary exploratory analyses regarding the relationship between single habitat variables and bird abundance within plots. Initially only elevation and slope appear correlated with avian abundance. Mature forest plots with larger mean basal area are likely to be older stands than plots with smaller basal areas. Since older forests have more open canopies and, therefore, higher structural diversity than maturing forests, I expected study sites with greater mean total basal area per plot to have higher species diversity (see Figure 18 above). This relationship was confirmed in the bivariate regression results shown in Figures 14 and 15. Correlations between avian species diversity and other variables such as tree size, percent coniferous trees, percent large snags, veteran trees, understory diversity, patch size or connectedness should also be investigated (Lertzman, pers. comm.) and will be presented in the final report. It is clear that multivariate approaches to investigating habitat relationships or preferences are the next step to evaluating habitat quality for each or all of the selected focal species.

Disturbance Factors

In keeping with the Ministry of Forests management policy, the Ecological Reserve 48 has not been logged or otherwise impacted by human disturbance. The location is relatively remote, approximately a 45 minute steep forested hike upwards from rural land use with no nearby roads. This tends to deter unauthorized human use. It provided a good baseline comparison to all other study sites for various factors of disturbance. In contrast, Central Park and Green Timbers Urban Forest appeared to be the most disturbed sites based on trail density, human use and proximity to roads and dense urban land use. Central Park had intense overall use by sports enthusiasts for exercise, tennis and public sports events, and was used primarily by the Asian community for recreation, Tai Chi, cultural and religious group outings, special exercise classes, etc. Metrotown and the Skytrain are directly adjacent on the north side. Traffic was heavy on all other sides which are bordered by main travel routes. Green Timbers Urban Forest is bisected 3 times by 2 highways and a hydro throughway, and there was a complex network of trails. It is surrounded by high density housing, and was a popular walking and running area. However, there were dense inner patches of forest which were relatively unused and might account for the lower number of observations of people (Figure 16). Most other parks also had dense trail networks, but had relatively less human use than Central Park.

Recording plane observations was not in the original survey protocol; however, it became clear shortly after the start of the field season that the level of noise associated with heavy air traffic was significant during many survey intervals. Although, my ability to hear birds was often compromised for several seconds, how this noise influenced the bird community, if at all, is unknown. It might be assumed that if, at times, I could not hear particular birds, that birds, in turn, could not hear their conspecifics. If this is true, noise associated with planes and helicopters may at times impact the effectiveness of various vocalizations between and within species, especially during the breeding season. Although parks varied in their disturbance events, planes arrived at a mean of one in 20 minutes over the field season during bird point observations. Two airports with large international and commercial cargo flights, and significant small engine traffic from the inland province and the Sunshine Coast, contribute to the density of air traffic, especially in Lighthouse Park. Further research is necessary to clarify whether there is significant disturbance to wildlife as a result.

Other disturbance factors have yet to be analyzed such as exotic species abundance. Some disturbances will be evaluated on a spatial scale using GIS as described below.

GIS Analysis

Compiling and digitizing avian and habitat data for each study site will provide a map resource base for planners and managers to use in future regional monitoring efforts or site-to-site comparisons. The proposed spatial analyses will include measures of proximity to paved surfaces, surrounding urban density, relative edge effect, patch isolation or connectedness, and fragmentation.

PRELIMINARY CONCLUSIONS

It would be premature, at this stage in the analyses to attempt to draw firm conclusions from the results of both avian and habitat analyses and what they imply for the proposed indicator species, or to claim to have met all of the objectives of the research project. There are, however, some tentative inferences we can make from a preliminary review of summary statistics. 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 may also be important indicators of disturbance. In contrast, both Townsend’s and black-throated gray warblers may act as important indicators of a lack of disturbance and 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 forest may be an indication of similar habitat needs being met but on a variety of smaller scales.

There are considerable analyses that I have yet to conduct over the next year to complete the final report. These will include more in-depth investigation of each of the focal species within each study site. Bivariate analyses of avian and plant diversity metrics will be completed. Multivariate methods will be used to derive habitat indices for each focal species or groups of focal species. GIS analysis will present various measures of disturbance and provide maps of avian diversity and habitat at each of the study sites. Comparisons of all these analyses to those of more pristine sites within the same biogeoclimatic zone are necessary to derive a precise definition of habitat quality. We can then begin to assess each of the study sites for quality with regard to the specific habitat requirements of each of the relevant focal species. This work will ultimately contribute important information necessary to evaluate the selected focal species as indicators and act as a basis for future monitoring plans.

Future deliverables.
A final report including GIS-based resource maps will be submitted to the Georgia Basin Ecosystem Initiative Management Committee and the Ministry of Water, Land and Air Protection on completion of a Masters Degree and is anticipated during the fall of 2004 or spring of 2005.

MRM TIMELINE to January 2005

Task	Deadline	Procedure
Preliminary Report	Semester 2004-1	Submit a preliminary research report to MWLAP including summary statistics and preliminary analysis with a predicted timeline for completion of Final Project Report
Literature Review	Semester 2004-1/2	Study relevant literature, write a synopsis
Completion of Course Work	Semester 2004-2	A total of 12 courses completed for Masters degree requirements
Data Analyses	Semester 2004-2	Completion of detailed and comprehensive analyses to meet the objectives of the project and propose recommendations for future research and management
GIS Mapping	Semester 2004-2	Assess wildlife-habitat relationships and map priority habitat areas of selected focal species to meet future monitoring objectives
Report Writing	Semester 2004-3	Writing in preparation for project defense, publications and final report to be submitted to MWLAP
Project Defense	Semester 2004-3/2005-1	To academic committee and other interested parties
Final Report	Semester 2004-3/2005-1	Submission of a final report including maps to the SFU academic department, MWLAP and the GBEI on completion of requirements for a Masters degree

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APPENDIX 1. List of regional avian indicator species selected for conserving biodiversity in the Greater Vancouver Region (Lee and Rudd 2002).

Common Name	**Latin Name**
American Bittern	*Botaurus lentiginosus*
Barn Owl	*Tyto alba*
Black-bellied Plover	*Pluvialis squatarola*
Black-throated Gray Warbler	*Dendroica nigrescens*
Brown Creeper	*Certhia americana*
Cooper's Hawk	*Accipiter cooperii*
Great Blue Heron	*Ardea herodias fannini*
Marsh Wren	*Cistothorus palustris*
Northern Harrier	*Circus cyaneus*
Northern Pintail	*Anas acuta*
Pileated Woodpecker	*Dryocopus pileatus*
Red-breasted Nuthatch	*Sitta canadensis*
Rufous Hummingbird	*Selasphorous rufus*
Short-eared Owl	*Asio flammeus*
Spotted Towhee	*Pipilo maculatus*
Townsend's Warbler	*Dendroica townsendi*
Yellow Warbler	*Dendroica petechia*

APPENDIX II. List of all avian species detected within each study site both during and after bird point surveys.

Species Code	Common Name	Latin name	Belcarra	Bowen Eco Reserve	Central	Green Timbers	Lighthouse	Mundy	Robert Burnaby	Sunnyside	Tynehead	Watershed	Wickenden
ALFL	Alder Flycatcher	*Empidonax alnorum*							x				
AMCO	American Coot	*Fulica americana*				x							
AMGO	American Goldfinch	*Carduelis tristis*	x		x	x	x	x	x	x	x	x	x
AMKE	American Kestrel	*Falco sparverius*			x			x					
AMRO	American Robin	*Turdus migratorius*	x	x	x	x	x	x	x	x	x	x	x
ANHU	Anna's Hummingbird	*Calypte anna*					x						
BAEA	Bald Eagle	*Haliaeetus leucocephalus*		x	x	x	x	x		x		x	
BTPI	Band-tailed Pigeon	*Columba fasciata*	x					x		x			
BAOW	Barred Owl	*Strix varia*	x	x		x	x		x		x	x	x
BEWR	Bewick's Wren	*Thryomanes bewickii*			x	x		x	x	x	x	x	
BLOY	Black Oystercatcher	*Haematopus bachmani*					x						
BLSW	Black Swift	*Cypseloides niger*		x		x	x						
BCCH	Black-capped Chickadee	*Poecile atricapilla*	x		x	x	x	x	x	x	x	x	x
BHGR	Black-headed Grosbeak	*Pheucticus melanocephalus*	x		x	x	x	x	x	x	x	x	x
BTGW	Black-throated Gray Warbler	*Dendroica nigrescens*	x	x	x	x	x	x	x		x		x
BLGR	Blue Grouse	*Dendragapus obscurus*	x			x							
BOGU	Bonaparte Gull	*Larus philadelphia*										x	
BRCR	Brown Creeper	*Certhia americana*	x	x	x	x	x	x	x	x	x	x	x
BHCO	Brown-headed Cowbird	*Molothrus ater*			x	x	x	x	x	x	x	x	x
BUSH	Bushtit	*Psaltriparus minimus*				x							
CAGO	Canada Goose	*Branta canadensis*	x				x	x					
CATE	Caspian Tern	*Sterna caspia* Pallas								x			
CAVI	Cassin's Vireo	*Vireo cassinii*						x	x	x			
CEWA	Cedar Waxwing	*Bombycilla cedrorum*	x	x	x	x	x	x	x	x	x	x	
CBCH	Chestnut-backed Chickadee	*Poecile rufescens*	x	x	x	x	x	x	x	x	x	x	x
COLO	Common Loon	*Gavia immer*						x					
COME	Common Merganser	*Mergus merganser*					x						
CORA	Common Raven	*Corvus corax*	x	x	x	x	x	x	x	x		x	x
COHA	Cooper's Hawk	*Accipiter cooperii*	x		x	x		x		x			
DEJU	Dark-eyed Junco	*Junco hyernalis*	x	x	x	x	x	x	x	x	x	x	x
DCCO	Double-crested Cormorant	*Phalacrocorax auritus*					x						
DOWO	Downy Woodpecker	*Picoides pubescens*				x	x	x		x	x		
EUST	European Starling	*Sturnus vulgaris*			x		x				x		x
EVGR	Evening Grosbeak	*Coccothraustes vespertinus*								x		x	
GWGU	Glaucous-winged Gull	*Larus glaucescens*	x		x		x			x		x	x
GCKI	Golden-crowned Kinglet	*Regulus satrapa*	x	x	x	x	x	x	x	x	x	x	x
GCSP	Golden-crowned Sparrow	*Zonotrichia atricapilla*		x									
GBHE	Great Blue Heron	*Ardea herodias fannini*				x		x			x		
GHOW	Great Horned Owl	*Bubo virginianus*						x			x		
HAWO	Hairy Woodpecker	*Picoides villosus*	x	x	x	x	x	x	x	x	x	x	x
HAFL	Hammond's Flycatcher	*Empidonax hammondii*	x			x	x	x		x	x		
HETH	Hermit Thrush	*Catharus guttatus*	x										

(CONT'D)

(CONT'D)

Species Code	Common Name	Latin name	Belcarra	Bowen Eco Reserve	Central	Green Timbers	Lighthouse	Mundy	Robert Burnaby	Sunnyside	Tynehead	Watershed	Wickenden
HUVI	Hutton's Vireo	*Vireo huttoni*	x		x	x	x	x	x	x	x	x	x
KILL	Killdeer	*Charadrius vociferus*									x		
MACW	MacGillivray's Warbler	*Oporornis tolmiei*		x			x	x		x			x
MGNW	Magnolia Warbler	*Dendroica magnolia*	x								x		
MALL	Mallard	*Anas platyrhynchos*			x	x							
NOFL	Northern Flicker	*Colaptes auratus*	x	x			x	x					x
NOGO	Northern Goshawk	*Accipiter gentilis atricapillus*	x										
NSWO	Northern Saw-whet Owl	*Aegolius acadicus*								x			
NOCR	Northwestern Crow	*Corvus caurinus*	x	x	x	x	x	x	x	x	x	x	x
OSFL	Olive-sided Flycatcher	*Contopus cooperi*	x			x	x	x	x	x	x		
OCWA	Orange-crowned Warbler	*Vermivora celata*	x			x	x	x			x	x	
OSPR	Osprey	*Pandion haliaetus*				x							x
PSFL	Pacific-slope Flycatcher	*Empidonax difficilis*	x	x	x	x	x	x	x	x	x	x	x
PIWO	Pileated Woodpecker	*Dryocopus pileatus*		x	x	x	x	x	x	x	x	x	x
PISI	Pine Siskin	*Carduelis pinus*	x	x	x	x	x	x	x	x	x	x	x
RECR	Red Crossbill	*Loxia curvirostra*	x	x		x	x	x		x			x
RBNU	Red-breasted Nuthatch	*Sitta canadensis*	x	x	x	x	x	x	x	x	x	x	x
RBSA	Red-breasted Sapsucker	*Sphyrapicus ruber*	x	x			x	x	x		x		x
REVI	Red-eyed Vireo	*Vireo olivaceus*			x	x	x	x	x	x	x	x	
RTHA	Red-tailed Hawk	*Buteo jamaicensis*			x	x		x	x	x		x	
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*				x							
RODO	Rock Dove	*Columba livia*				x				x			
RUHU	Rufous Hummingbird	*Selasphorous rufus*	x			x	x	x	x	x	x	x	x
SAVS	Savannah Sparrow	*Passerculus sandwichensis*				x					x		
SSHA	Sharp-shinned Hawk	*Accipiter striatus*				x	x	x			x	x	
SOSP	Song Sparrow	*Melospiza melodia*	x	x	x	x	x	x	x	x	x	x	x
SPTO	Spotted Towhee	*Pipilo maculatus*	x		x	x	x	x	x	x	x	x	x
STJA	Stellar's Jay	*Cyanocitta stelleri*	x	x	x	x	x	x	x	x	x	x	x
SWTH	Swainson's Thrush	*Catharus ustulatus*	x	x	x	x	x	x	x	x	x	x	x
TOSO	Townsend's Solitaire	*Myadestes townsendi*											x
TOWA	Townsend's Warbler	*Dendroica townsendi*	x	x	x	x	x	x	x	x	x	x	x
VATH	Varied Thrush	*Ixoreus naevius*	x	x	x	x	x	x	x	x	x	x	x
VGSW	Violet-green Swallow	*Tachycineta thalassina*					x						
WAVI	Warbling Vireo	*Vireo gilvus*	x		x		x	x	x	x	x	x	x
WETA	Western Tanager	*Piranga ludoviciana*	x	x	x	x	x	x	x	x	x	x	x
WWPE	Western Wood-Pewee	*Contopus sordidulus*	x		x	x	x		x	x	x	x	x
WCSP	White-crowned Sparrow	*Zonotrichia albicollis*	x			x	x		x	x	x		
WWCR	White-winged Crossbill	*Loxia leucoptera*	x										
WIFL	Willow Flycatcher	*Empidonax traillii*	x								x		
WIWA	Wilson's Warbler	*Wilsonia pusilla*	x		x	x	x	x	x	x	x	x	x
WIWR	Winter Wren	*Troglodytes troglodytes*	x	x	x	x	x	x	x	x	x	x	x
WODU	Wood Duck	*Aix sponsa*				x							
YEWA	Yellow Warbler	*Dendroica petechia*				x							
YRWA	Yellow-rumped Warbler	*Dendroica coronata*	x		x		x	x	x	x	x	x	x
UNKN	Unknown Species	n/a	x	x	x		x	x	x	x	x	x	x
Total Species	**87**		49	30	41	55	55	53	42	50	49	42	41