

USING POINT-DISTANCE SAMPLING OF BIRD DENSITIES AS AN INDICATOR OF FOREST ECOLOGICAL INTEGRITY - A PILOT STUDY IN KEJIMKUJIK NATIONAL PARK

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SUMMARY

Changes in the presence and abundance of bird species may reflect changes in the components or processes of a forest ecosystem. The objective of this 5-year pilot study is to assess the use of birds as indicators of the ecological integrity of forests within a national park. Towards this goal, spatial and temporal relationships within and among bird populations and other ecosystem components and processes will be quantified. Monitoring of various indicators of ecosystem structure and function will be integrated at the level of the plot. Replicate plots will be randomly selected from stands of two zonal forest types, hemlock-dominated and hardwood-dominated stands. The 10-min point count will form the basis of the bird monitoring protocol. To determine the number of sample sites to establish in the first year of this project, point-count data from the existing Kejimikujik forest bird monitoring program was subject to power analysis for trend detection. Results for 24 bird species inhabiting mesic sites in the park suggested 50 points in each forest type may be necessary to detect population changes in common species over a reporting interval of 5 yrs. Comparison of point count data and territory maps indicate deficiencies in data collected using either 50-m fixed radius and unlimited-radius point counts. Furthermore, detection distances differed among species. This pilot study will thus employ point-distance sampling, from which densities can be estimated. Data obtained for individual species will be used separately and to calculate species richness and diversity. Indices based on species assemblages and ecological guilds will be developed and assessed for their sensitivity to ecological change at the stand level.

1. INTRODUCTION

Conspicuous, popular, and relatively easy to identify, birds are being monitored for their own sake in a variety of programs in Canada and elsewhere. Long-term programs focus on monitoring trends in bird populations at local (1), regional (2), or continental scales. Data from the North American Breeding Bird Survey (BBS), collected since 1966, have revealed widespread declines in many species (3, 4) and currently inform conservation priorities of government and non-government organizations.

The use of birds as indicators for ecological integrity has recently been reviewed with respect to the process of indicator selection (5). Other recent studies have shown that bird species assemblages reflect gradients in forest canopy cover, fragmentation, and urbanization (6, 7, 8). For protected areas and their greater ecosystems, the abundance of particular bird species are often notably different inside and outside of the park (9). Birds are proving to be useful indicators of terrestrial ecosystem change at the landscape scale.

Whether birds also reflect the ecological integrity of forest ecosystems at the local scale—within the park—is the subject of the present study. Birds have been proposed as indicators of ecosystem structure or biodiversity at Kejimikujik NP (10). Beginning in May 2003, birds will be monitored along with several other ecosystem components (e.g., plants, salamanders, lichens) and processes (e.g., soil decomposition, nutrient status) in a 5-year pilot study to develop plot-level monitoring of ecological integrity. This paper describes the strategies underlying the forest bird portion of this pilot study and uses data from an existing forest bird monitoring program in Kejimikujik NP (11, 12) to assess and select protocols.

2. METHODS

Two zonal forest types were selected based on previous forest inventories and soil and drainage maps: eastern hemlock forest and hardwood-pine mixedwood on mesic sites characteristic of the region. This

design was chosen to reduce within-forest type variability and to reflect average conditions of the park's forests.

Avian biodiversity data for 55 mesic sites were selected from the database of the Kejimikujik forest bird monitoring program (12). Ten-minute point counts were conducted between late May and early July, 1997-2000 and 2002. Each year, two visits ≥ 10 days apart were made to each site. The maximum number of singing males or pairs detected on the two visits was used as the measure of annual abundance for each species at each site (2). Abundance was calculated for all birds detected (unlimited radius data) and for observations truncated at 50-m from the point (fixed radius data) (11).

Power analysis was conducted on unlimited-radius count data using MONITOR (13) and PASS (14) software. The 24 most commonly detected territorial species across the 55 sites were selected and data were analyzed for each species separately for the number of point-count sites at which the species occurred. Data used in the PASS analysis included the overall mean and standard deviation of counts per point for each species, whereas MONITOR used the mean and standard deviation for each point to simulate changes over time. The power to detect trends using linear regression was set at 0.90 and the significance level at 0.20, for annual monitoring over a period of 5 years.

For three years (1997-1999), two larger areas, each containing 5 of the point count sites, were surveyed by spot-mapping on ≥ 8 mornings to map territories. The forest on these two plots is similar to the target forest of the pilot study. The Hardwood Plot was 35 ha of hardwood-dominated mixedwood, mainly red maple, red oak, white pine, white birch, yellow birch, and American beech. The Hemlock Plot was 20 ha of eastern hemlock-dominated forest with scattered white pine, red spruce, red maple, yellow birch, and white birch. Mean abundance for the 20 most common species from fixed and unlimited radius points for the 5 points was compared to number of territories that intersected circles of 50-m, 75-m, and 125-m centered on the 5 points.

Species differences in detectability were explored by plotting detection distances for birds with many detections in sites that were sampled with distance estimation in Kejimikujik NP in 1998.

3. RESULTS

3.1 Power to detect trends

The mean abundance of the 24 most common species ranged from 2.6 to 0.4 birds per point (Table 1). Standard deviations (SD) were similar across species, but coefficients of variation (CV) ranged from 0.33 to 1.28 and paralleled trends in the amount of change detectable for the species over a 5-yr period. Assuming a single data point per year (because data for the two visits will be combined into a single value for trend analysis), power analysis using PASS (14) indicated that a change in abundance of $\leq 30\%$ would be detected for 17 species and a smaller change of 10-15% would be detectable for 4 species (Table 1). If sample sizes are doubled by counting both visits (not shown), a change of $\leq 30\%$ would be detectable for all species except the Veery, and a change of 10-15% would be detectable for 9 species.

Table 1. Abundance for 24 forest bird species in Kejimikujik NP and amount of change detectable with 0.90 power if *N* points are monitored annually for 5 years.*

Species	<i>N</i> points	Mean	SD	CV	% change
Ovenbird	55	2.6	0.87	0.33	10
Northern parula	55	1.7	0.68	0.40	10
Yellow-rumped (myrtle) warbler	54	2.2	0.91	0.41	15
Red-eyed vireo	51	2.1	0.87	0.41	15
Least flycatcher	40	2.2	0.88	0.40	20
Blue-headed (solitary) vireo	55	1.7	0.84	0.49	20
Ruby-crowned Kinglet	47	1.3	0.66	0.51	20
American redstart	27	1.4	0.71	0.51	20
Hermit thrush	55	1.2	0.69	0.58	20
Eastern wood pewee	30	1.0	0.52	0.52	25
Black-throated green warbler	34	1.1	0.61	0.55	25
Dark-eyed junco	52	1.3	0.75	0.58	25
Blackburnian warbler	44	1.2	0.72	0.60	25
Magnolia warbler	31	1.5	0.82	0.55	30
Yellow-bellied sapsucker	35	1.0	0.65	0.65	30
Black-capped chickadee	47	1.0	0.75	0.75	30
Red-breasted nuthatch	49	0.8	0.61	0.76	30
American robin	34	0.9	0.64	0.71	35
Black-and-white warbler	35	0.7	0.51	0.73	35
Swainson's thrush	41	0.9	0.69	0.77	35
Black-throated blue warbler	36	0.7	0.59	0.84	40
Bay-breasted warbler	31	0.7	0.61	0.87	40
Golden-crowned kinglet	37	0.6	0.54	0.90	40
Veery	25	0.4	0.51	1.28	65

* maximum number of males or pairs detected per point per year in unlimited radius counts; sample size for power analysis = 5 yrs x *N* points where species occurs

Different results were obtained if counts were summed across sites for annual totals and the mean and SD were calculated from annual totals ($N = 5$). In this case, CVs were <0.5 for all species except the Veery, and were ≤ 0.25 for 15 of the 24 species. The Ovenbird had the highest annual abundance (114 birds) and the lowest CV (0.06). Using these data for annual totals and a sample size of 275 (55 sites x 5 yrs), power analysis using PASS indicated that a change as small as 15% would be detectable for most of the species.

Power analysis using MONITOR (not shown) gave less optimistic results than PASS, perhaps because the program simulates trends for each point independently (mean and SD for each point are required inputs), rather than the overall mean and SD used by PASS.

3.2 Abundance estimates

Mean abundances of birds at 5 point count sites in the two target forest types are shown in Tables 2-3. Counts at 50-m and unlimited distances were similar for most of the warblers (except Ovenbirds) and other species with low-amplitude songs (e.g., Least Flycatcher, Golden-crowned Kinglet, Brown Creeper, Dark-eyed Junco). Consistently more birds with louder vocalizations (e.g., thrushes, vireos, and woodpeckers) were detected in unlimited than in fixed radius counts. Somewhat smaller differences between the two types of counts were found for the same species on the Hardwood Plot (Table 2) than on the Hemlock Plot (Table 3).

Table 2. Number of detections for point counts in the Hardwood Plot compared to the number of territories intersected by circles drawn around the same points on territory maps. Data are averages of the 5 points across all 3 years (1997-1999) for the 20 most abundant species on the plot, ranked by the similarity of abundance in unlimited-radius points to number of territories intersected by a 50-m radius circle.

Species	Point count data		Circles on territory maps		
	50-m	Unlimited	50-m	75-m	125-m
Yellow-bellied sapsucker	0.47	1.20	1.20	1.60	2.53
Red-eyed vireo	1.80	2.73	2.93	4.40	6.93
Ovenbird	2.13	3.13	2.80	3.60	5.53
Northern parula	2.07	2.27	2.80	4.00	6.27
Least flycatcher	2.60	2.80	3.67	7.13	12.27
Eastern wood pewee	0.47	0.93	1.33	2.00	2.67
American redstart	1.00	1.13	1.73	3.33	5.33
American robin	0.80	0.93	1.47	1.93	3.47
Blue-headed (solitary) vireo	0.53	1.00	1.93	2.87	4.20
White-breasted nuthatch	0.13	0.27	0.53	0.80	1.07
Yellow-rumped (myrtle) warbler	0.80	0.93	1.87	2.73	4.33
Black-and-white warbler	0.33	0.33	0.73	1.13	1.67
Hermit thrush	0.33	0.60	1.40	2.13	3.47
Dark-eyed junco	0.60	0.67	1.67	2.67	3.40
Red-breasted nuthatch	0.07	0.27	0.87	1.20	1.73
Hairy woodpecker	0.20	0.33	1.13	1.47	2.20
Veery	0.13	0.20	0.87	1.00	1.60
Downy woodpecker	0.07	0.27	1.20	1.40	1.93
Black-capped chickadee	0.20	0.20	0.93	1.20	2.53
Brown creeper	0.00	0.00	0.87	1.07	1.40

Table 3. Number of detections for point counts in the Hemlock-dominated stand compared to the number of territories intersected by circles drawn around points on territory maps. Data are averages of the 5 points across all 3 years (1997-1999) for the 20 most abundant species on the plot. Species are ranked by similarity of unlimited-radius counts to number of territories intersected by the 50-m radius circle.

Species	Point count data		Circles on territory maps		
	50-m	Unlimited	50-m	75-m	125-m
Bay-breasted warbler	0.87	0.93	0.93	1.53	2.20
Ovenbird	1.07	2.13	2.00	2.60	3.93
Ruby-crowned kinglet	0.27	0.93	0.87	1.33	1.73
Northern parula	1.00	1.47	1.67	2.47	3.93
Black-throated green warbler	1.20	2.07	2.60	3.40	5.07
Yellow-rumped (myrtle) warbler	1.13	1.47	1.87	2.60	4.20
Blackburnian warbler	1.87	1.87	2.40	3.13	4.93
Red-breasted nuthatch	0.53	0.73	1.13	1.73	2.53
Dark-eyed junco	0.73	1.07	1.67	2.27	3.53
Hermit thrush	0.20	0.80	1.27	1.47	2.67
Blue-headed (solitary) vireo	0.73	1.27	2.33	3.13	4.53
Golden-crowned kinglet	0.73	0.73	1.40	1.80	2.60
Red-eyed vireo	0.40	1.00	1.93	2.40	3.87
Swainson's thrush	0.27	0.60	1.53	1.80	3.00
Black-capped chickadee	0.20	0.47	1.27	1.47	2.20
American robin	0.13	0.27	0.73	0.87	1.20
Hairy woodpecker	0.00	0.20	0.67	0.80	1.00
Brown creeper	0.27	0.27	1.07	1.07	1.40
Veery	0.07	0.13	0.67	0.93	1.40
Winter wren	0.13	0.13	0.67	0.87	0.93

Abundances from point counts were compared with the number of territories that intersected circles of radii 50, 75, and 125m drawn on territory maps (Tables 2-3). Overall, the most similar data sets were unlimited point counts and simulated counts for 50-m radius circles, especially for species that sing regularly (e.g., most of the wood-warblers). For many species that vocalize less regularly (e.g. thrushes, woodpeckers), however, only 20-50% of the territorial males within a 50-m radius were actually detected during the 10-min point counts.

3.2 Detectability

Distances to singing birds were estimated for 12 species in point counts conducted in 1998. Mean detection distances ranged from 35 m for Least Flycatchers to 75 m for the thrushes (Fig. 1). As a group, the wood-warblers had the smallest detection distances, with relatively few heard >60 m, whereas the songs of the Ovenbird, vireos, and thrushes were typically heard for ≥ 100 m.

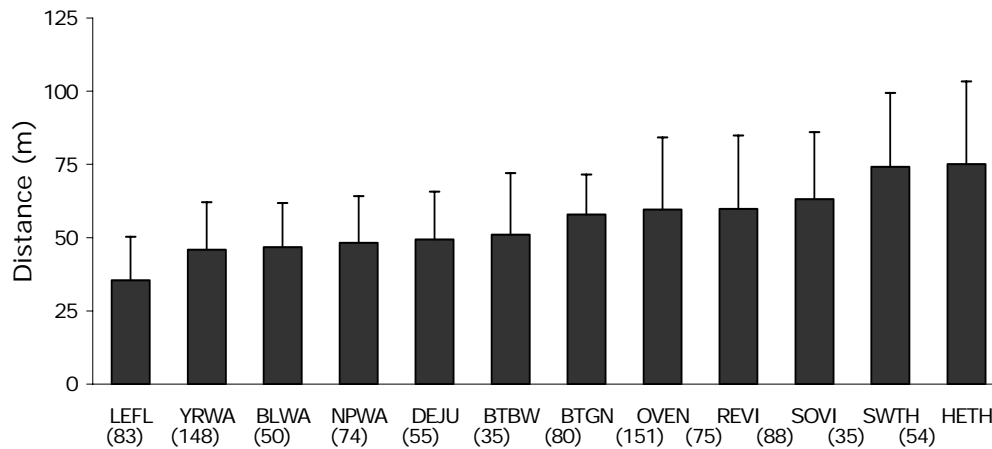


Figure 1. Mean distances (+1 SD) at which 12 species of forest birds were detected. Data from 58 point count sites in Kejimikujik NP, sampled twice by one observer (CAS) in 1998. Number of detections in parentheses

4. DISCUSSION

4.1 Point count protocols

Results of power analysis differed with species, strategy for determining sample size, and the level at which the mean and SD were calculated for the 5 annual counts. When annual totals were used to estimate parameters, the power to detect small trends (10-15%) over a 5-yr period was large (0.90) for common species. When parameters were calculated for each of the 55 points separately, about twice as much change in abundance would have to occur to be detectable with the same power. Another statistical issue is whether the appropriate sample size for power analysis should be based on the number of points or whether this should be doubled since two visits are made to each site. Data from the two visits, however, are combined to obtain a single annual abundance value, which would be used in regression analysis to test for trend significance. These issues will be addressed further in the 5-year pilot study.

To assess the reliability of counts, data were simulated for the Hardwood and the Hemlock plots based on territory maps. Data for limited and unlimited radius counts were compared with the numbers of territories that intersected circles of 50, 75, and 125 m radii. Much variation was observed among the species. Overall, the unlimited-radius point count data, which include all detections, were most similar to the number of bird territories intersected by 50-m radius circles. These values were most similar for species that sing regularly (e.g., wood-warblers, Red-eyed Vireo) and least similar for species that sing less frequently (e.g., Brown Creeper, Black-capped Chickadee, thrushes).

Another explanation for the differences among species noted above is the distances over which their voices are detectable. Least Flycatchers vocalize regularly but their voices are difficult to hear even 50 m away in Kejimikujik NP. Many wood-warbler species have low amplitude songs, usually detectable for ≤ 60 m. Only the Ovenbird, which sings its distinctive song loudly (detectable at ≥ 100 m), as well as frequently, had a higher abundance in the field counts than in the simulated counts.

For birds with low-amplitude voices, unlimited-radius counts were similar to limited-radius counts. For birds with louder voices, unlimited-radius counts were considerably higher than limited-radius counts, but still far below the number of territories within 50-m radius circles. Considering the apparent lack of consistency in the accuracy of abundances across species, it seems inappropriate to use the data for either limited or unlimited counts to calculate species richness or diversity indices. Spot-mapping of territories, which provides actual densities is likely too intensive to apply to most parks.

An obvious improvement would be to calculate actual densities from point counts (15). The solution to this problem, which will be applied in this pilot study, is distance-sampling and estimation of densities using the software DISTANCE (16). In distance sampling, the distances to each bird detected are recorded. Laser range-finders, training, and regular self-testing are essential to achieve accurate distance estimation.

Detections can be placed into distance categories to simplify data collection. A minimum of 5 distance bands are required; because it is more difficult to estimate further distances, the bands can span a greater distance interval at higher distances (16). In the pilot study, the following distance bands will be used: 0-15, 15-30, 30-45-45-60, 60-80, 80-100, 100-125, 125-150, and >150 m. It should be possible to place distances accurately into bands and still have 5 bands of data for species with low-amplitude voices.

Another requirement of distance sampling is a large number of detections (≥ 60) for each species in each forest type in order to fit species-specific and habitat-specific detection functions, the basis for estimation of densities. The detection function attempts to model the decline in detectability over distance, such that the probability of detection at a given distance is specified by a mathematical function.

Considering the results of the power analysis and the need for a large number of detections for density estimates, target sample sizes for the pilot study were set at 50 points in each of the two forest types. The initial study design for plot-based monitoring of ecosystem components included 6 stands, 3 of each type, which would provide enough area to establish only about 30-35 bird points. For 20 of the 24 species in the existing data set, however, the mean number of birds detections per point was < 2.0 . Thus 15-20 additional points will be needed to bring the total to 50 points per forest type, which should provide for enough detections for all of the common species.

After two years of data collection in the pilot study, effectiveness of protocols will be assessed. In particular, sample sizes (number of points) will be examined in the context of power to detect trends and ability to model detectability. If 50 points per stand type are deemed excessive, some or all of the points established outside of the 6 main stands could be dropped for the remainder of the pilot study.

Adding points would likely be prohibitively costly. Sampling 100 points twice per season is the maximum that can be expected from a single field worker. Weather permitting, one person can survey all 100 points twice during a 5 wk period. An experienced bird surveyor is essential because of the importance of identifying every vocalizing bird to species and estimating its distance.

5.2 Birds as Indicators of Ecological Integrity

Much recent attention has focused on relating bird abundance or species presence to variation in habitat. Bird community indices of biotic integrity have been developed by grouping birds by guild (17) or response to habitat features, such as canopy closure (6). Indices like these are useful at the landscape scale, but whether they are sensitive enough at the local scale requires further study. Guild-based indicators will be developed during the first two years of the pilot study.

Birds may be good candidate indicators of subtle changes that would be more difficult or expensive to measure otherwise, or when the biological response to environmental change is the desired metric (18). For example, wood thrush presence reflects soil pH, presumably through a response to calcium content of soil influenced by acid rain (19). Changes in ecological integrity within a forest stand may indeed be subtle and not detectable with tools that work well at landscape scales.

One expected change within a national park is forest succession. Forests change gradually over time due to aging and disturbances like fire and windthrow. Long-term research at local scales has documented changes in bird species abundance with natural changes in habitat structure associated with the aging of forests (20, 21). At Kejimikujik NP, forest succession had lead to closure of the canopy in previously disturbed stands. During the 35-yr period following park establishment, large changes in bird populations have been associated with this vegetation change (22).

Whether birds are useful indicators of ecological integrity at the stand level is the main focus of this pilot study. To answer this question will require quantitative measures of bird populations and other aspects of ecosystem structure and function. In other words, a clear link must be demonstrated between

variation in the forest ecosystem and in bird species presence, abundance, and possibly behaviour (18, 23). Most indicators have never been rigorously tested (24), and birds are no exception.

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