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OBSERVER AND ANNUAL VARIATION IN WINTER BIRD POPULATION STUDIES

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There are many factors which influence the results of avian censuses and surveys and thus affect the comparability of results across plots (Weber and Theberge 1977, Shields 1979, Ralph and Scott 1981). For example, the time (Shields 1977), duration (Engstrom and James 1984), and date of survey (Järvinen et al. 1977), the experience (Faanes and Bystrak 1981) and hearing ability (Cyr 1981) of observers, weather conditions (Falk 1979), and plot size (Engstrom and James 1981) are all known to affect survey results. If valid inferences are to be made concerning avian populations and communities by censusing different plots, the variation due to these factors must be assumed to be much less than the between-plot variation. Such an assumption is often made for between-observer and between-year variation in census results. If in fact these assumptions are invalid, erroneous inferences may result.

Variation due to observer and year of survey in breeding season studies has been examined by several authors (Enemar et al. 1978, Rotenberry and Wiens 1980, Ralph and Scott 1981, Wiens 1981a). The effects of these sources of variation on survey results in non-breeding communities, using methods such as the Winter Bird Population Study (WBPS), have never been investigated.

The WBPS is a method of estimating bird species' abundances during winter on sample plots (Kolb 1965). Several surveys (generally 6–10) are made of a plot during which the identity and location of each bird encountered is noted on a map of the plot. Many of the plots surveyed using this method are published annually in American Birds. Detailed descriptions of the WBPS method are presented by Kolb (1965) and Robbins (1972).

Differences between observers in WBPSs may be smaller than in breeding season studies due to the decreased importance of aural detection cues, so critical in breeding season studies (Cyr 1981, Faanes and Bystrak 1981). Large between-year environmental variation is thought to result in increased variation in species' populations (Järvinen 1979). Thus, inter-year differences in winter bird assemblages could be much larger than in breeding communities due to the larger between-year environmental variation.

In the present paper I test the hypothesis that the variation between observers and years in WBPSs may in fact be large enough, relative to between plot variation, to introduce considerable bias into comparisons between plots. The results of this test have implications for the use of the WBPS method in ecological surveys and environmental impact assessment.

METHODS

Study plots and field methods.—Seven plots were sampled for this study: Sherwood, Cedarvale, Bayview, Park Drive, Rosedale, Upper Gerrard, and Chatsworth. All plots are located in Toronto, York RM, Ontario. They are urban habitat islands occupying river valleys and contain varying proportions of wooded and open habitats. Full descriptions of the plots are given in Smith et al. (1982). Three of the study plots were sampled in 2 successive years: Sherwood, Cedarvale, and Bayview (Table 1). During the second year, three observers independently sampled the Sherwood plot (Table 1). The three observers differed considerably in their ornithological experience: observer GF had over 40 years bird-watching experience and had conducted many breeding bird censuses (BBCs) and breeding bird surveys; observer PS had about 10 years bird-watching experience and had conducted several BBCs and WBPSs; observer DK had about 2 years bird-watching experience and had conducted one WBPS. The years of coverage of each plot and the number and initials of observers who conducted the sampling are detailed in Table 1.

Bird surveys were conducted according to the WBPS method outlined by Kolb (1965) and Robbins (1972) with the modifications noted in Smith et al. (1981). Between 5 and 10 counts were conducted on each plot. Time and weather information was recorded and the identity, number, and location of all birds noted on base maps of each plot. Summaries of the results of the WBPSs are given in Smith et al. (1981, 1982).

During the survey of Sherwood by three different observers, special precautions were taken to avoid confusing observer differences with differences due to other factors. Survey route and time of day (morning 07:30–11:00) were standardized. Wind velocity (Beaufort scale), ambient temperature, and percent snow and cloud cover were measured as potential covariates. Maximum and minimum temperatures were obtained from a local weather station, also as potential covariates. A non-parametric multivariate rank test (Puri and Sen 1971: 187) for all the above variables revealed no significant differences in the conditions and timing of surveys by different observers. Any differences in WBPS results can thus be attributed to actual differences among observers. Differences in personal methodology were not minimized as this experiment was a test of how important these differences may be. Specific differences are mentioned below.

Sampling design and statistical methods.—The WBPSs conducted for this study are organized as three separate "experiments" or sample surveys. These sample surveys estimate variance due to plot, year, observer, and sampling error. The sampling of three plots by the same observers in two successive years conforms to a 3×2 completely randomized factorial design. Both among-plot and between-year variation are estimated in this sample survey. However, among-plot variance cannot be separated from among-observer variation. The sampling of four plots in 1 year by one observer conforms to a four treatment, single factor, completely randomized design (Steele and Torrie 1980:137). From this set of surveys among-plot variance was estimated. The one plot sampled in one year by three observers is equivalent to a three treatment, single factor, completely randomized design (Steele and Torrie 1980:137). Among-observer variance can be estimated using these results. All of these designs estimate sampling error.

The estimation of sampling error in bird surveys often involves replication in space or, as in this case, replication in time (Gates 1981). The problem with these types of replication

TABLE 1
A LIST OF STUDY PLOTS INDICATING THE OBSERVERS AND YEARS OF COVERAGE FOR EACH

Plot	1979–80	1980–81
Sherwood	1 (GF)[a,b]	3 (GF, DK, PS)[a,b]
Cedarvale	1 (DK)	1 (DK)
Bayview	1 (DB)	1 (DB)
Park Drive	1 (PS)	—
Rosedale	1 (PS)	—
Upper Gerrard	1 (PS)	—
Chatsworth	1 (PS)	—

[a] Number of observers in each year.
[b] Observers' initials in parentheses.

is that each sample is not independent of the others and hence, sampling error is underestimated (Gates 1981, Rice 1981). As a result, inferences made on the basis of such estimates of sampling error can be subject to Type I errors (i.e., the rejection of the null hypothesis when in fact it is true). Despite these problems, replication in time is one of the few means of estimating variance in bird surveys and is widely used (e.g., Enemar et al. 1978, Anderson et al. 1981, Robbins 1981, Skirvin 1981).

A number of statistical methods were used in the analysis of the bird survey data. The primary statistical tool employed was analysis of variance, both parametric (Steele and Torrie 1980) and non-parametric (Puri and Sen 1971). Parametric analysis of variance was used when its underlying assumptions were met. These assumptions are that the dependent variable is normally distributed and that its variance is homogeneous within the different cells of the design (Steele and Torrie 1980:167). When these assumptions were not met, non-parametric methods were used. The use of analysis of variance tests the importance of plot, observer, and annual variance relative to sampling error. To examine the importance of plot, observer, and annual variance with respect to each other I used the F-test for comparing the estimated variances from different "experiments" (Snedecor and Cochran 1980:252). An assumption of this test is that the sampling errors of the different "experiments" are equal. This assumption was tested using the same F-test. The power of all the statistical tests was limited by the small number of observers, plots, and years used.

Two other statistical techniques were applied to the data prior to analysis of variance. These techniques were "jackknifing" (Routledge 1980, Smith and van Belle 1984) and rarefaction (Simberloff 1978, Tipper 1979). These methods relate to the measurement of diversity and will be outlined below in that context.

Variables used.—To analyze the importance of observer and annual variation, a series of variables were selected. These variables are commonly used in the analysis of bird survey data. The analyses can conveniently be divided into analyses of avian community composition, community structure, and species population densities. Community composition is used here to refer purely to the identities of the species which compose the communities and the between-plot variation in the identity and abundance of these species. Conversely, community structure is defined here as those aspects of community organization which are unrelated to the species composition. Community structure parameters frequently used are: overall avian abundance or density, number of species, the frequency distribution of the species' relative densities, and associated measures of diversity and evenness.

Diversity is a concept which includes the two components, number of species or species richness, and evenness, the degree to which each species is equally represented in the community. There is a large, often acrimonious, literature on the measurement of diversity (for example see Dennis et al. 1979). A great many indices have been used and their relative merits debated (Hill 1973, Pielou 1975, Simberloff 1978, Patil and Taillie 1979, Alatalo 1981, Siegel and German 1982). Many diversity indices combine richness and evenness into one index. Hill (1973) and Patil and Taillie (1979) have both shown that many of these diversity indices are related and vary primarily in the weight placed on rare species. These measures of diversity are dependent on sample size. This dependency has led to the use of rarefaction as an alternative to diversity indices (Simberloff 1978, James and Rathbun 1982). Rarefaction is a statistical means of estimating the number of species expected in a random sample of individuals from a collection (James and Rathbun 1982). The method allows the comparison of the species richness of collections or samples with varying numbers of individuals.

In light of the variety of means to measure community diversity, four widely used methods were employed here. The number of species per survey was used as a simple indicator of species richness. Two indices which incorporate evenness were used, H′ ($-\Sigma\ p_i \ln p_i$) and N_2 ($1/\Sigma\ p_i^2$). These indices are both subject to bias when based on a small sample and may have a non-normal frequency distribution. The jackknife statistical procedure can be used to remove bias, stabilize the frequency distribution, and provide an estimate of the variance of H′ and N_2. Simply put, the jackknife procedure involves deleting one replicate, pooling all other samples, and calculating the indices. Each sample is deleted in succession. The full details of jackknifing are given by Routledge (1980). Jackknifed estimators of H′ and N_2 were calculated using a FORTRAN program written by the author. The fourth method used to measure diversity was rarefaction. The expected number of species [$E(S_n)$] in a random sample of n individuals drawn from N individuals (where $n < N$) was calculated for each survey. From the total number of birds on each survey (N) the number randomly selected (n) was varied from five by increments of five to the closest value to N. The calculations were performed using a FORTRAN program based on that in Simberloff (1978). The method of calculating $E(S_n)$ for each plot corresponds to the replication model outlined by Tipper (1979). Because the total number of birds, N, varies from survey to survey, $E(S_{15})$ was used for most statistical tests. Fifteen was the largest value of n for which $E(S_n)$ can be calculated for virtually all the surveys. A "knot-by-knot" comparison (sensu Tipper 1979) of the complete rarefaction curves of different observers and years was made using multivariate analysis of variance (MANOVA).

Two measures of evenness were applied to the data, $E_{2,1}$ [N_2/N_1] (Hill 1973) and $F_{2,1}$ [$(N_2 - 1)/(N_1 - 1)$] (Alatalo 1981). These variables were calculated from the jackknifed estimators of N_1 [$\exp(H')$] and N_2. Total number of birds detected per survey divided by the area of the plot was the measure of total avian abundance. This variable was log-transformed to meet the assumptions of analysis of variance.

The examination of differences between plots, years, and observers in the species composition of avian surveys is one of multivariate differences between "treatments." Hence, multivariate analysis of variance is the most appropriate method for statistical analysis (Stroup and Stubbendieck 1983). However, many species' abundances did not conform to the normal distribution, even after transformation. As a result, a non-parametric multivariate rank test (Puri and Sen 1971, Sarle 1983) was used to compare variance due to observers, years, and plots to sampling error. Observer, year, and plot differences could not be compared to each other with these data. To investigate such differences several observers must conduct WBPSs on several plots in several years.

To test the importance of observer and annual variance in estimating species' densities it was necessary to select species which were common during both years, on all plots, and

TABLE 2

COMPARISON OF OBSERVER, ANNUAL, PLOT, AND SAMPLING VARIANCE AS SOURCES OF ERROR IN ESTIMATING COMMUNITY STRUCTURE

Variable	Observer vs sampling variance (df = 2,20)	Annual vs sampling variance (df = 1,42)	Plot vs observer variance (df = 3,2)	Plot vs annual variance (df = 3,1)	Annual vs observer variance (df = 1,2)
Total density	0.39[a]	24.65[b]***	20.15*	0.90	51.34*
Diversity					
Number of species per survey	1.58	17.13***	2.42	0.07	10.38
H′	1.18	4.51[b]*	5.05	1.75	2.88
N_2	0.43	0.88	22.64*	47.31	3.24
$E(S_{15})$	0.08	0.45	20.45*	3.30	6.19
Evenness					
$F_{2,1}$	0.05	0.02	60.94*	317.53*	0.21
$E_{2,1}$	0.26	1.27	59.41*	32.62	1.87

[a] *F*-ratios of the variance due to the first factor to that due to the second.
[b] *** $P \leq 0.001$, * $P \leq 0.05$.

in surveys by all observers. This was needed to meet the assumptions of analysis of variance. On this basis six species were chosen: Downy Woodpecker, Blue Jay, Black-capped Chickadee, White-breasted Nuthatch, Northern Cardinal, and Dark-eyed Junco (see Appendix for scientific names). The species' densities were log-transformed to normalize their frequency distributions and stabilize their variances.

RESULTS

The results of comparing the variances attributable to different factors are presented in Tables 2 and 3. Values given in the tables are *F*-ratios or the ratios of the variances from two different sources. These values form the basis of the statistical tests and are an indication of the relative size of variances from the two sources.

Community structure—observer variance.—Observer variance was not significantly larger than sampling variance for any measure of community structure (Table 2, column 1). A comparison of rarefaction curves ($E[S_n]$ for n = 5, 10, 15, 20, 25) for the three observers using a multivariate analysis of variance also revealed no significant difference between observers ($F = 1.59$, $P = 0.17$). Between-plot variance was between 2 and 60 times greater than observer variance and significantly larger for total density, N_2, $E(S_{15})$, $E_{2,1}$, and $F_{2,1}$ (Table 2, column 3). The ratio of annual variance to observer variance was highly variable between measures (Table 2, column 5). Annual variance was significantly greater than observer variance for total density but not any other community structure variables.

TABLE 3
COMPARISON OF OBSERVER, ANNUAL, PLOT, AND SAMPLING VARIANCE AS SOURCES OF ERROR IN ESTIMATING SPECIES ABUNDANCES

Species	Observer vs sampling variance (df = 2,20)	Annual vs sampling variance (df = 1,42)	Plot vs observer variance (df = 3,2)	Plot vs annual variance (df = 3,1)	Annual vs observer variance (df = 1,2)
Downy Woodpecker	1.23[a]	0.01	1.60	231.00*	0.01
Blue Jay	0.17	0.00	31.62*	4535.33*	0.01
Black-capped Chickadee	4.68*	13.81***	5.44	1.50	3.63
White-breasted Nuthatch	1.54	7.57**	22.92*	1.05	26.02*
Northern Cardinal	1.84	12.51**	3.10	0.49	6.31
Dark-eyed Junco	0.21	6.85*	33.39*	0.75	44.48*

[a] F-ratios of the variance due to the first factor to that due to the second.
* $P \leq 0.05$.
** $P \leq 0.01$.
*** $P \leq 0.001$.

Thus, confounding of annual and observer variation appears more serious than confounding observer and plot variation.

Community structure—annual variance.—Some measures of community structure showed a strong annual effect while others did not. Annual variance in total density, the number of species per survey, and H′ were significantly greater than sampling variance (Table 2, column 2). In addition, a comparison of the rarefaction curves ($E[S_n]$ for n = 5, 10, 15, 20, 25, 30, 35) for different years and plots combinations using MANOVA revealed a significant difference between years ($F = 2.56$, $P = 0.03$). However, between-year differences in N_2, $E(S_{15})$, $E_{2,1}$, and $F_{2,1}$ were not significantly greater than sampling error (Table 2, column 2). Between-plot variance in N_2, $E_{2,1}$, $F_{2,1}$, $E(S_{15})$, and H′ was greater than annual variance but significantly only for $F_{2,1}$ (Table 2, column 4). For total density and number of species per survey, between-plot variance was smaller than annual variance (Table 2, column 4). Summarizing, between-year variation is a substantial source of variation and thus comparisons between plots sampled in different years should be made cautiously.

Community composition.—Overall estimated community composition was not significantly different between observers (multivariate rank test, $\chi^2 = 40.0$, df = 41, $P = 0.51$). Four of the 24 species, however, showed significant univariate differences among observers. The four species were Mallard, Screech Owl, Black-capped Chickadee, and American Goldfinch. Differences in detecting Screech Owls were due to the use of a tape recording by observer GF. Differences in the numbers of goldfinches appear to be related to perceptual difficulties in estimating numbers of each species in mixed flocks of siskins and goldfinches (compare the results of the observers in the Appendix). Observer PS made special efforts not to double-count individual Black-capped Chickadees due to their tendency to follow the surveyor. This resulted in his substantially lower estimate of the abundance of this species (Table 3 and Appendix).

Overall community composition was not significantly different between years (multivariate rank test, $\chi^2 = 43.05$, df = 34, $P = 0.14$). However, 16 of the 34 species showed significant univariate differences between years.

The magnitude of observer, plot, and annual variance in estimating community composition cannot be compared here due to the limited nature of the experiment (see Methods). Although only small observer differences were observed here, caution is necessary in interpreting compositional differences, particularly if observer and plot variation cannot be separated. Compositional differences between years may be considerable and a larger sample of years could be used to examine this in more detail.

Species populations.—As might be expected, the effect of observer and annual differences was quite variable among species, as shown in Table 3. Differences between years tended to be substantially larger than between observers (Table 3, columns 1 and 2). Between-plot variation was significantly greater than that between observers for three of the six species examined (Table 3, column 3). The plot/annual and annual/observer variance ratios were highly variable among species (Table 3, columns 4 and 5).

Confounding observer variance with plot variance appears less serious than confounding observer and annual variance. But observer variance was up to 60% as large as plot variance. Thus, comparisons of the abundances of common species in WBPSs from different plots surveyed by different observers should be done with caution. A knowledge of between-observer and between-plot variance is necessary to rigorously interpret such comparisons.

DISCUSSION

In any ecological survey which uses data from different observers and years there are biases introduced which may obscure real ecological patterns. How important these and other sources of bias are is a function of the amount of variation between the samples or plots within the whole survey. As beta diversity and between-plot variation in community structure increases, the importance of other sources of error decreases. The analyses presented in this paper illustrate how the importance of such biases may be examined.

Other evaluations of the WBPS method have focused on its efficiency and sampling adequacy for estimating community structure and species' abundances (Brewer 1972, 1978; Robbins 1972, 1981). Robbins (1972, 1981) has examined the question of what constitutes a sufficient number of replicates for the estimation of species abundances. Clearly, the validity of between-plot comparisons of species' abundances is dependent on factors such as: the abundance, frequency of occurrence, and other species' characteristics, the size of between-observer, between-plot and sampling variances, and the number of replicates in each WBPS. It is apparent from Robbins' (1981) work that the number of replicates needed to reasonably estimate species' abundances is larger than for estimating community structure. This may be particularly true if jackknifed estimators of community structure are used (also see Routledge 1980, Smith and van Belle 1984). Such estimators remove bias due to small sample size. The use of jackknifed estimators of species' abundances may also be a means of increasing the accuracy of estimating these quantities.

Observer variation.—A number of studies have found observer variation to be rather small in breeding season studies using the mapping method (Enemar 1962, Snow 1965, Hogstad 1967, Enemar et al. 1978). These studies have used only observers of considerable competence. Other authors have found substantial differences between observers with varied levels of experience (Faanes and Bystrak 1981, O'Connor 1981). None of these studies has considered the magnitude of observer variation relative to that source of variation which is of most importance to the particular study.

Studies of observer differences have for the most part focused on differences in estimating community structure or individual species populations. Faanes and Bystrak (1981), however, used a distance measure to examine overall observer differences in estimating composition. With the increasing use of multivariate statistical techniques to analyze avian community data it is important to investigate the effect of observer bias on such analyses. Hall and Okali (1978) examined the effect of observer bias on the extraction of compositional gradients in vegetation data using principal component analysis. They found that observer bias obscured several gradients actually present in the data. Results presented here indicated little difference in estimating community composition between the observers used. This may not always be the case and should be tested in each investigation.

Many of the sources of error identified in census work in breeding avian communities are equally important in surveying winter bird assemblages. Some of these sources of error, such as weather variables and time and duration of survey, can be controlled and/or statistically tested to detect differences between plots, as was demonstrated here. The estimation of observer variation requires field trials, but these are required if the WBPS is to be applied rigorously. In the present study, not all observers involved in the larger study were tested but those representing the full range of experience were.

The results presented here suggest that observer variance in WBPSs may be less than in breeding season studies. This may be due to the reduced importance of aural cues—the use of which requires considerable expertise, lack of obstructing vegetation, and decreased species richness (alpha diversity). However, observer variation is primarily due to perceptual and methodological differences between people and thus will vary with the set of observers used.

Annual variation.—Annual variation in ecological communities and its effect on the testing of hypotheses have recently attracted considerable attention (Rotenberry and Wiens 1980; Anderson et al. 1981; Wiens 1981a, b; Rice et al. 1983; Rogers 1983). Many studies have noted substantial annual variance in avian community structure (Anderson et al. 1981, Wiens 1981a). Others, such as Järvinen and Väisanen (1976) assert that certain community structural features, e.g., diversity, vary little between years while features such as density vary considerably more. Furthermore, Anderson et al. (1981) have shown that the magnitude and direction of annual change in community structure can be different on different plots.

The importance of annual variation is obviously a function of the scale of the study as well as the quantity and heterogeneity of the data employed. The data presented here illustrate that, within the current study framework, annual variation is a substantial souce of variance. Its importance must be assessed within the context of each study.

Rotenberry and Wiens (1980) noted no significant differences in breeding bird community composition between years that differed considerably in environmental conditions. Data presented here indicate that substantial compositional change may occur in winter bird assemblages between years.

High annual variability in environmental conditions has been linked to high species turnover rates and greater variation in avian community structure (Järvinen 1979). Annual variation in the avian community in highly variable environments may be as important as spatial variation. Annual variation in community structure and composition may be due to any number of factors, e.g., local and/or large scale variation in individual species populations. Wiens (1981b) suggests that large annual variation may be due simply to a random redistribution of territories in unsaturated habitat. Whatever its source, such variation cannot be assumed to be small relative to between-plot variance.

Wiens (1981a) examined the effects of inter-year variation in census results on the testing of an hypothesis relating community structure to environmental variables. His treatment shows that such variation can influence inferences which are made using plot data. Ignoring this variance could lead to results that are artifacts of the methodology.

In the years since its inception, many plots have been sampled using the WBPS method. Yet very little analysis and hypothesis testing have been done using these data. This contrasts markedly with the number of studies using data from breeding bird censuses. This is partially due to the relative scarcity of tests of the method's sensitivity to bias, compared to the exhaustive testing of methods used in breeding season studies. At the same time, WBPSs increasingly are being used in the environmental impact assessment process to document the effects of development or management policies on avian populations and communities. Ignoring the sources of bias in the WBPS method can only decrease the credibility of such assessments.

As the sources of bias in the WBPS are critically examined, the method can be refined to reduce the effect of such sources of error. Thus, users of the method may be able to apply it in a more rigorous manner.

SUMMARY

The assumption that observer and annual (between-year) variation in winter bird population studies (WBPS) results is small relative to between-plot variation was examined. The implications of the results for the use of the WBPS for hypothesis testing in ecological surveys and environmental impact assessments are discussed.

Data from a survey of winter avian assemblages in urban areas were used to test the hypothesis. Variables often used in avian community analysis were examined. Measures of community structure included several indices of diversity and evenness and overall abundance. Species composition was investigated using a multivariate rank test. Variation in estimating the abundance of six common species was also examined.

Observer variation in estimating community structure, community composition, and species' abundances was found to be small relative to both sampling and between-plot variance. Thus, in the context of the present study, observer bias did not appear important except in estimating number of species per count and H'. Annual variation in community structure, composition, and species' abundances was relatively large for many variables. Annual variance was seldom smaller than observer variance and only sometimes less than variance between plots. Thus, comparisons between plots surveyed in different years or between surveys conducted by different observers on the same plot in different years should be made cautiously.

The generality of these results is unknown and will vary. This paper indicates a method for the evaluation of these and other sources of bias in the WBPS.

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APPENDIX

Survey Results by Three Different Observers

Variable	Observer DK	Observer GF	Observer PS
Mallard (*Anas platyrhynchos*)	—	0.3	1.6
Red-tailed Hawk (*Buteo jamaicensis*)	0.7[a]	0.6	—
Rock Dove (*Columba livia*)	—	0.1	—
Mourning Dove (*Zenaida macroura*)	3.7	11.5	17.4
Screech Owl (*Otus asio*)	—	0.8	—
Pileated Woodpecker (*Dryocopus pileatus*)	—	0.1	—
Hairy Woodpecker (*Picoides villosus*)	0.3	0.5	0.2
Downy Woodpecker (*P. pubescens*)	2.5	1.9	3.8
Blue Jay (*Cyanocitta cristata*)	0.5	1.0	0.6
Common Crow (*Corvus brachyrynchos*)	2.8	1.5	3.4
Black-capped Chickadee (*Parus atricapillus*)	11.5	8.4	5.0
White-breasted Nuthatch (*Sitta carolinensis*)	4.5	3.2	3.6
Red-breasted Nuthatch (*S. canadensis*)	—	0.4	0.6
American Robin (*Turdus migratorius*)	1.2	2.7	4.0
Cedar Waxwing (*Bombycilla cedrorum*)	4.2	0.1	0.2
European Starling (*Sturnus vulgaris*)	0.8	4.1	4.4
House Sparrow (*Passer domesticus*)	1.5	0.3	—
Northern Cardinal (*Cardinalis cardinalis*)	2.5	3.6	4.0
Common Redpoll (*Carduelis flammea*)	0.6	2.1	0.4
Pine Siskin (*C. pinus*)	5.0	6.0	2.8
American Goldfinch (*C. tristis*)	4.2	0.5	4.6
Dark-eyed Junco (*Junco hyemalis*)	8.7	9.9	11.6
White-throated Sparrow (*Zonotrichia albicollis*)	0.2	0.6	0.2
Song Sparrow (*Melospiza melodia*)	0.3	—	—
Total no. birds per survey	56.5	60.3	68.4
Diversity			
No. species per survey	10.8	13.0	11.4
N_2	11.16	9.69	8.95
H'	2.698	2.553	2.465
$E(S_{15})$	7.22	7.36	7.19
Evenness			
$F_{2,1}$	0.6914	0.7243	0.6947
$E_{2,1}$	0.7809	0.7962	0.8590
Number of surveys	6	10	5

[a] Values represent mean number of each species detected per count.