Sample Size and Allocation of Effort in Point Count Sampling of Birds in Bottomland Hardwood Forests[1]

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Abstract: To examine sample size requirements and optimum allocation of effort in point count sampling of bottomland hardwood forests, we computed minimum sample sizes from variation recorded during 82 point counts (May 7-May 16, 1992) from three localities containing three habitat types across three regions of the Mississippi Alluvial Valley (MAV). Also, we estimated the effect of increasing the number of points or visits by comparing results of 150 four-minute point counts obtained from each of four stands on Delta Experimental Forest (DEF) during May 8-May 21, 1991 and May 30-June 12, 1992. For each stand, we obtained bootstrap estimates of mean cumulative number of species each year from all possible combinations of six points and six visits. ANOVA was used to model cumulative species as a function of number of points visited, number of visits to each point, and interaction of points and visits. There was significant variation in numbers of birds and species between regions and localities (nested within region); neither habitat, nor the interaction between region and habitat, was significant. For $\alpha = 0.05$ and $\beta = 0.10$, minimum sample size estimates (per factor level) varied by orders of magnitude depending upon the observed or specified range of desired detectable difference. For observed regional variation, 20 and 40 point counts were required to accommodate variability in total individuals (MSE = 9.28) and species (MSE = 3.79), respectively, whereas ± 25 percent of the mean could be achieved with five counts per factor level. Sample size sufficient to detect actual differences of Wood Thrush (*Hylocichla mustelina*) was >200, whereas the Prothonotary Warbler (*Protonotaria citrea*) required <10 counts. Differences in mean cumulative species were detected among number of points visited and among number of visits to a point. In the lower MAV, mean cumulative species increased with each added point through five points and with each additional visit through four visits. Although no interaction was detected between number of points and number of visits, when paired reciprocals were compared, more points invariably yielded a significantly greater cumulative number of species than more visits to a point. Still, 36 point counts per stand during each of two breeding seasons detected only 52 percent of the known available species pool in DEF.

Despite the extensive literature on estimating numbers of terrestrial birds (e.g., Scott and Ralph 1981), general agreement over a standardized protocol for monitoring Neotropical migrant birds using point counts is only now being achieved (Ralph and others 1993). Required sample sizes using point counts and allocation of effort among points and visits to points are poorly understood. Monitoring efforts applied over a large region (e.g., lower Mississippi Alluvial Valley) need to accommodate local, habitat, and regional variation in Neotropical migratory bird species distribution and abundance. Only then can we hope to achieve optimum sampling protocols, i.e., provide sufficient ecological information with the least amount of sampling effort.

This paper examines sample size requirements for point count surveys in bottomland hardwood forests of the Mississippi Alluvial Valley (MAV). Specific objectives were to determine (1) minimum sample size to accommodate the variation in bird species distribution and relative abundance throughout the MAV; (2) the optimum number of points to sample at each locality; and (3) the optimum number of counts at each point during a season.

Methods

Study Areas

For this paper, we compiled data from two studies. To estimate variability throughout the MAV, we developed a balanced study design that included three point counts at each of three localities within each of three habitats (Wet, Mesic, Dry). This sampling design was repeated in each of three regions (Southern, Central, Northern) of the lower MAV (i.e., 3 x 3 x 3 x 3) for a total of 81 point counts. Wet habitat localities were characterized by cypress (*Taxodium* sp.) or tupelo (*Nyssa* sp.). Mesic habitat localities were seasonally flooded, lowland flatwoods, whereas Dry habitat localities were ridges or rarely inundated bottomland forests. Each locality was >40 ha to accommodate three randomly selected points that were at least 250 m apart (Ralph and others 1993) and >200 m from the forest edge.

In addition, Delta Experimental Forest (DEF), Stoneville, Mississippi was the site of a 2-year study (1991-1992) examining the influence of forest management on breeding bird abundance and diversity (Smith 1991). DEF encompasses about 1,050 ha and represents one of the few remaining large (≥100 ha), contiguous bottomland forests in a 100-km radius.

Point Count Protocol

With few exceptions, we followed the general guidelines and procedures for point count censusing of birds by Ralph and others (1993). Point counts within the lower MAV were of 10-minute duration (with cutoffs at 3 and 5 min as well) and occurred during the first four hours after dawn (i.e., before 1000 CDT). Each point was visited once during May 7-16, 1992. An assistant estimated distance to each bird according to predefined landmarks and recorded data. Before each count began, distance to selected landmarks was estimated with a rangefinder (Ranging Optimeter 620, Ranging Inc., East Bloomfield, NY). Landmarks were used to assign birds seen or heard to one of three concentric distance bands: <25 m; 25 m to 50 m; or >50 m. When necessary, the

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rangefinder was used to verify the distance band within which individual birds should be recorded.

Briefly, we found (Smith and others 1993) that the 50-m distance band and a sampling period of 5 minutes provided the most favorable results with respect to recording number of species per unit effort. Therefore, for the purposes of this study, we will use only data recorded using those constraints.

On DEF, we established 25 randomly selected points within each of four stands: two silvicultural treatments and a paired control for each treatment. One treatment was a 1937 clearcut that regenerated naturally; the second underwent timber stand improvement cuts in 1937. Each control had not been managed since the last high-grade harvest (mid-1930's). To minimize the potentially confounding influence of treatment effects on habitat structure and probability of detection, we recorded birds seen or heard within a 20-m radius of each point.

Within each stand, each point was systematically sampled five to seven times during the 3-hour period following sunrise from May 8 to May 21 in 1991, and from May 30 to June 12 in 1992. A sampling schedule was implemented whereby each point within a stand was visited on separate days at a different time on each of the subsequent visits. Each census consisted of recording all birds seen or heard within 20 meters of the observer per minute, for a total of four minutes.

Data Analyses

Calculation of minimum sample size followed Neter and Wasserman (1974:492) for a specified α (probability of rejecting the null hypothesis when it should be accepted), β (probability of not rejecting the null hypothesis when it should be rejected), and ø, the non-centrality parameter (*appendix A*). Specifying ø requires determining how much factor (i.e., treatment) level means (e.g., region) must differ to represent a statistical difference (Neter and Wasserman 1974). For this paper we chose three different specifications for ø. The first reflected the observed variation of variables among each of the main effects, i.e., region, habitat, and locality. Here, the range of mean values observed for a dependent variable relative to each effect (e.g., mean number of species in each of the regions, or mean number of a species among habitats) was used to calculate ø. The other two specifications were arbitrary but represent extremes with respect to resolution: (1) sample sizes for a difference of ±0.25 to detect statistical significance if the greatest difference among factor levels was 0.25 birds, or 0.25 species, and (2) a precision of ±25 percent of the mean, which represents a coarser filter for investigating gross differences in species distribution and abundance.

From point count data recorded within DEF, we generated a matrix of mean cumulative number of species for censuses with all possible combinations of six points and six visits using the bootstrap procedure (Efron 1982). Within each stand, observations for each combination (e.g., two visits to each of four points) were obtained by randomly sampling the "population" of point counts (e.g., 150 counts: 6 visits to 25 points) recorded each year. For each randomly selected point count, location was constrained while successive visits were randomly selected. Each mean value was computed from 250 resampling iterations and represented an independent observation of a point x visit combination within the selected stand.

We used analysis of variance (ANOVA, GLM Procedure; SAS Institute, Inc. 1988:549) to determine whether significant variation in cumulative number of species occurred as a function of number of points, number of visits, or an interaction of points and visits. Scheffe's multiple comparison procedure was performed to determine which main effect means differed. We made an *a priori* simultaneous comparison using a contrast statement within the ANOVA (SAS Institute, Inc. 1988:560) to compare the 15 possible reciprocal combinations of points and visits that were conducted on Delta Experimental Forest.

Results and Discussion

Distribution of Point Counts

Although the proposed experimental design for the lower MAV study provided for a balanced design of 81 point counts (3 regions x 3 habitats x 3 localities x 3 counts), we did not find all three types of habitat in all localities. Specifically, only one Dry habitat locality was identified in the southern region, and one Wet habitat locality was not found in the Central region. Nonetheless, we generally followed our basic study design completing 82 10-minute point counts throughout the lower MAV during the period May 7-May 16, 1992 (Smith and others 1993).

On Delta Experimental Forest, Stoneville, Miss., we conducted 600 4-minute point counts from May 8 through May 21, 1991-six visits to 25 points in each of four stands. An additional 600 4-minute point counts were completed during the period May 30-June 12, 1992.

Variation among Point Counts and Minimum Sample Size

Nature and Extent of Point Count Variation

A critical aspect of this study was to characterize the nature and extent of variation that investigators may encounter in conducting point count censuses in bottomland hardwood forests. Only then can an appropriate study design with adequate sample sizes be developed (objective 1). There was significant variation in numbers of both individuals and species per count for the lower MAV. Mean number of individuals ranged from 10.8 birds/count in Wet habitat within the Central region to 20.0 birds/count in Mesic habitat within the Southern region. Corresponding values for species counts were 8.3 and 13.7, both in Wet habitat, within the Southern and Northern regions, respectively. Point counts in the Central region averaged the fewest number of individuals per census (13.2, s = 3.07); the Southern and Northern regions averaged 16.8 (s = 2.20) and 15.0 (s = 2.16), respectively. The Central region also averaged the fewest species per census (9.6, s = 1.93). Mean number of species per census in the Southern region was 10.2 (s = 1.74), whereas the Northern region averaged 11.2 (s = 1.70).

Variation among Localities and across Regions

Overall ANOVA models for both number of species and number of individuals were significant; differences between regions and localities nested within regions were significant, but neither habitat nor the interaction between habitat and region were significant (*table 1*). This result suggests that at the finer scale most of the variation in point counts occurs among locations, but less so among habitats. This may be because continuously forested habitats in the lower MAV are very similar; most habitats have comparable elevation and micro-relief, experience perennial inundation, and generally support forest cover types that are similar in composition and structure. In contrast, species composition and other habitat features presumably show appreciable variation among regions.

Minimum Sample Size

There are two major approaches to estimating minimum sample size. The "non-power method" (Ott 1977) calculates the minimum sample size for a specified difference between two means, given the variance in the data, but considers only the probability of making a Type I error. The "power method" (Neter and Wasserman 1974) calculates minimum sample size relative to the probability of making Type I and Type II errors. The power method dictates minimum sample sizes greater than or equal to the non-power method and thus is more conservative.

Minimum sample size estimates for the lower MAV varied greatly according to the variable measured and scale of resolution (*table 2*); only extremely large sample sizes would accommodate all possible measurements. The sample size (given a particular variance) determines the magnitude of the difference between factor means that can be detected with statistical significance. If the difference between two means is small relative to their variance, the power of the test will probably be low. To achieve greater power in this situation usually requires very large sample sizes, even approaching infinity. Unfortunately, selecting an acceptable power for each test may often be largely subjective.

Nevertheless, one does not want all comparisons for all species to be significant. If all tests were significant, there would be little information about the relative importance of each factor in determining bird distributions. Thus, it is necessary to choose a minimum sample size that is reasonable for identifying biologically important factors, yet is achievable with reasonable effort. We calculated minimum sample sizes for a variety of differences among means, and for several different variables: number of species, number of individuals, and for species exhibiting different distributions and abundances throughout the lower MAV (*table 2*). Also, *appendix B* summarizes minimum sample sizes for 20 selected species with differences among localities across all three regions. (Scientific names of species included in *appendix B* are included in an appendix of this volume.)

For each variable in the table, we presented four minimum sample sizes (*table 2*). Note that these are minimum sample sizes for each level of a factor. Thus, the total sample size for a study comparing three regions would be three times the number given in the table. The numbers in the column called "actual difference" represent minimum sample sizes that would have been required to detect the difference in factor means according to the variation incorporated in the point counts conducted in the lower MAV. (Note that the MSE [mean square error], mean, and range were also calculated from these censuses.) The actual difference could not be statistically significant for variables with sample sizes greater than about 82, which was the number of counts conducted in the lower MAV. For example, differences among habitats (*table 2*) could have been significant only for the Prothonotary Warbler (*Protonotaria citrea*) or Red-eyed Vireo (*Vireo olivaceus*).

Sample sizes for a difference of ±0.25 birds are those that would be required for statistical significance if the greatest difference among factor levels was 0.25 birds (or 0.25 species). Since this value designates an absolute change in abundance, the relative difference identified as statistically significant will vary with the mean. When the mean is large, such as mean total number of species or number of individuals, the relative difference represented by ±0.25 is small (about 2.4 percent and 1.7 percent of the means for regional total species and total individuals, respectively). In contrast, our regional estimate of mean number of Wood Thrush (*Hylocichla mustelina*) was 0.23 per census (*table 2*); a difference of ±0.25 individuals becomes an increase or decrease of >100 percent of the mean. This was the situation for the majority of species in the lower MAV, including nine of the 20 more common species reported in *appendix B*.

Perhaps a better approach for estimating minimum sample sizes of individual species is to specify some relative change in population abundance. For this reason, we included a column in *table 2* that summarizes sample sizes for detecting differences of ±25 percent of the mean. This translates into a maximum difference among treatment means of 50 percent of the overall mean. One can readily compute sample sizes for a wide range of relative changes in abundance by simply increasing or decreasing the disparity between treatment means and overall mean (i.e., μ_j - μ; Neter and Wasserman 1974:493). Selecting an appropriate magnitude of relative change will depend on the objectives of the research or monitoring program. We calculated sample sizes required to detect variation of ±25 percent of the mean because such a difference should frequently reflect biologically meaningful changes, and it represents an achievable goal for most public and private land managers. For more detailed research endeavors such as modeling population dynamics or population viability analyses of endangered species, consistent detection of smaller relative changes may be necessary.

Finally, to provide a different perspective on the question of sample size, we presented minimum difference detected among factor level means (given the MSE) with a sample size of 70 (*table 2*). We initially selected a sample size of 70 for this exercise because it was the largest sample size value presented in the table of curves (TABLE A-10, Neter and Wasserman 1974:827). Since then, however, we recognized that 70 point counts was an achievable goal and would probably accommodate the needs of most public and private land managers. Although the values for minimum sample size vary widely, most of the values are ≤70, and many fall into the range of 40-60, especially for differences that probably are biologically meaningful. For species that have large differences relative to their overall mean (e.g., Prothonotary Warbler), sample size could be much smaller, especially if the study were designed carefully with respect to selected

Table 1-ANOVA ***tables (overall models) for the number of species and individuals per count. (Region and habitat were treated as main effects with patch nested within region).***

Effect	Degrees of freedom	*F*	*P > F*
	Species		
Region	2	5.70	0.005
Habitat	2	0.32	0.730
Region*Habitat	4	1.11	0.357
Locality (Region)	6	2.82	0.017
Within	67		
	Individuals		
Region	2	7.46	0.001
Habitat	2	0.61	0.546
Region*Habitat	4	0.31	0.871
Locality (Region)	6	2.33	0.042
Within	67		

Table ***2-Minimum sample sizes calculated for several variables according to the power method with several detectable difference values among factor level means. MSE, mean, range, and actual difference were calculated from observed variation among factor levels in this study. (Unless otherwise noted, $\alpha = 0.05$ and $\beta = 0.10$).***

				Sample size required for			
Variable	MSE[1]	Mean[2]	Range[3]	Actual Difference[4]	±0.25 Birds[5]	±25 percent of mean[6]	Difference[7] detected if n = 70
Total species							
Region	3.791	10.30	1.53	41	>500	5	1.192
Locality	3.759	9.60	1.87	29	>500	5	1.187
Habitat	4.143	10.30	0.69	>500	>500	5	1.246
Total birds							
Region	9.283	14.95	3.56	20	>500	5	1.866
Locality	9.174	13.21	2.63	35	>500	6	1.855
Habitat	11.272	14.95	0.87	>500	>500	5	2.056
Northern Cardinal							
Region	1.292	1.59	0.48	>200	>200	53	0.696
Locality[8]	1.144	1.71	1.04	28	>200	44	0.655
Habitat	1.326	1.58	0.27	>200	>200	53	0.705
Prothonotary Warbler							
Region	0.563	0.95	1.38	9	58	70	0.453
Locality	0.571	0.57	0.35	>200	58	>200	0.463
Habitat	0.822	0.95	0.94	23	90	95	0.545
Red-eyed Vireo							
Region	0.358	0.52	0.79	15	37	>200	0.366
Locality	0.208	0.32	0.78	9	23	>200	0.279
Habitat	0.445	0.52	0.36	44	44	>200	0.408
Wood Thrush							
Region	0.232	0.23	0.13	>200	27	>200	0.295
Locality	0.151	0.18	0.24	58	15	>200	0.238
Habitat	0.235	0.23	0.03	>200	27	>200	0.297

[1]Mean Square Error of one-way Analysis of Variance, with three levels of treatment (for example, northern, central and southern region).
[2]Mean birds or species per count. This value is the same for Region and Habitat.
[3]Range between the means for the highest and lowest levels of treatment.
[4]Sample size that is required to get statistical significance for the actual observed difference among factor level means (range). Note that the minimum sample sizes in *table 2* were all calculated using a design with one factor and three factor levels. If more or fewer levels were used, this number would be slightly greater or smaller; however, the numbers in *table 2* are a useful approximation.
[5]Sample size that would be required to detect a significant difference of 0.25 birds (or species) above or below the overall mean.
[6]Sample size that would be required to detect a significant difference between two treatments that is between 25 percent above and 25 percent below the overall mean (that is, the difference between two treatment means of 50 percent of the overall mean).
[7]The difference (in number of birds) that could be significantly detected by a sample size of 70.
[8]Because locality was nested within region, no overall minimum sample size can be calculated for locality. The minimum sample sizes in this table were calculated from one-way ANOVA of the three patches within the central region because of the balanced sample size design.

variables and factor levels. An analysis of regional choices by Prothonotary Warblers at three factor levels would require 27 counts (nine point counts per factor level). Conversely, species that have more variation and exhibit smaller differences, such as the Northern Cardinal (*Cardinalis cardinalis*), would require larger sample sizes.

Multiple Points Versus More Visits to Points

We initially compared all possible combinations of six visits to each of six points by using ANOVA to model cumulative number of species as a function of number of points visited, number of visits to each point, and their interaction across all four stands. We considered each year independently because total species recorded in DEF during 1991 (S = 39) and during 1992 (S = 55) were substantially different, presumably because of late flooding in 1991. There was significant variation in mean cumulative species among number of points and among number of visits to each point, both in 1991 ($F \geq 91.30$, df = 35, $P < 0.0001$) and 1992 ($F \geq 89.78$, df = 35, $P < 0.0001$). There was no significant interaction between number of points and number of visits. However, the ANOVA model explained about 97 percent of the variation in mean cumulative number of species both in 1991 ($R^2 = 0.9673$) and 1992 ($R^2 = 0.9668$).

In 1991, cumulative number of species increased significantly with each added point through five points (*fig. 1*), but six points did not differ from five points (F = 3.19, Minimum Significant Difference = 0.7853, df = 108, $P <$ 0.05). Similarly, cumulative number of species increased with each revisit up to four visits to a point station, but four visits did not differ from five visits to a point station (F = 3.19, Minimum Significant Difference = 0.7853, df = 108, $P <$ 0.01). Also, as we increased the number of points from one to six, total increase in cumulative number of species (across all six visits) averaged 7.4 species across all stands and represented an addition of 20 percent of the species pool to our estimate. Total increase in cumulative number of species with six visits to a point station (across all six points) averaged 5.49 species, adding only 14 percent of the species pool to our estimate. In 1992, significant increases in cumulative number of species occurred with each added point through all six points, whereas significant increases with revisits occurred through four visits as in 1991 (F = 2.29, Minimum Significant Difference = 1.0451, df = 108, $P < 0.05$) (*fig. 2*). Average total increase in cumulative number of species with six points in 1992 was 11.82, a 21 percent increase in total number of species; six visits increased the total cumulative number of species by 8.9, a 16 percent increase in total number of species.

Although no interaction was detected between points and visits, when all possible paired reciprocals (e.g., one point-two visits vs. two points-one visit) were compared,

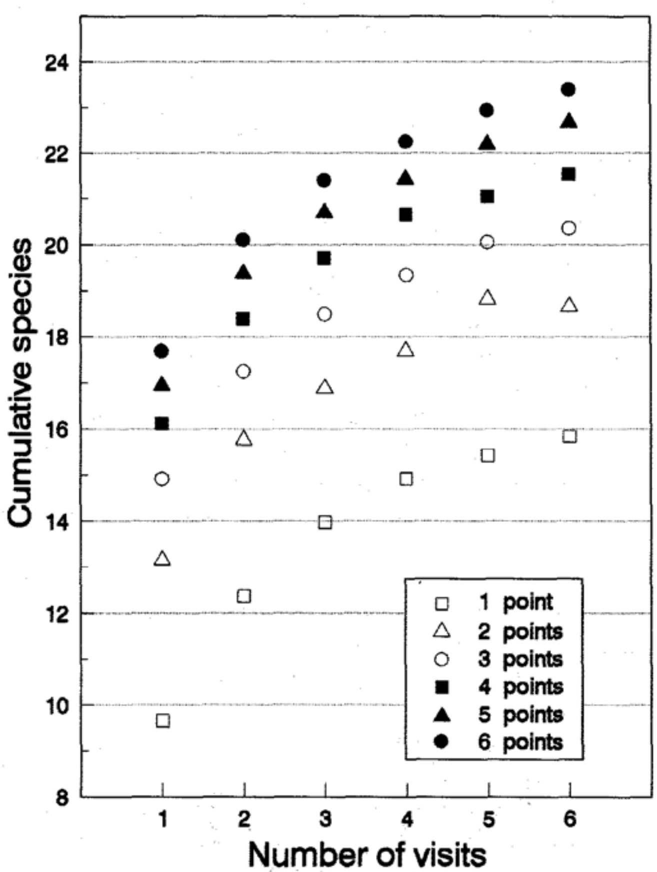

Figure 1-Cumulative number of bird species recorded during 1991 censuses for all possible combinations of six visits to each of six points on Delta Experimental Forest, Stoneville, Miss.

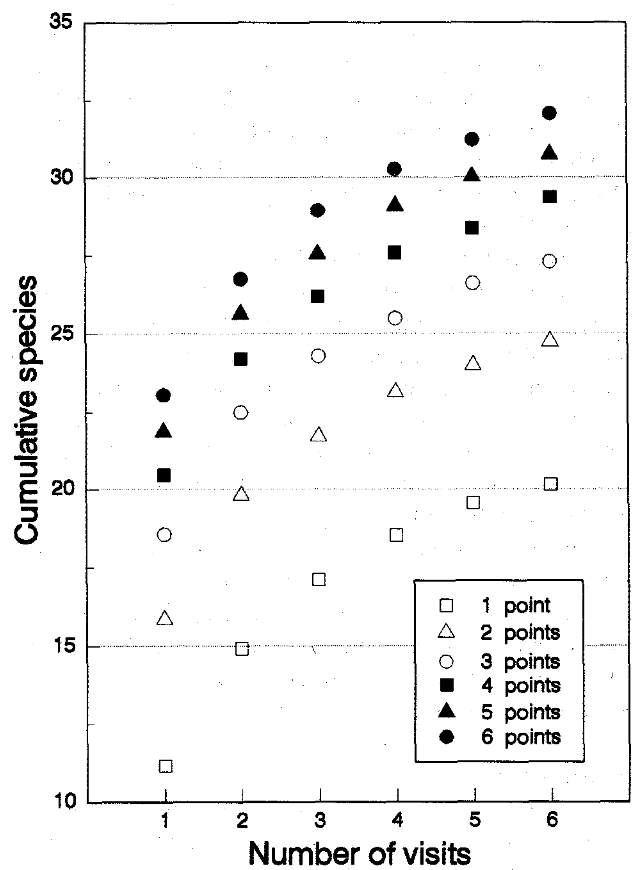

Figure 2-Cumulative number of bird species recorded during 1992 censuses for all possible combinations of six visits to each of six points on Delta Experimental Forest, Stoneville, Miss.

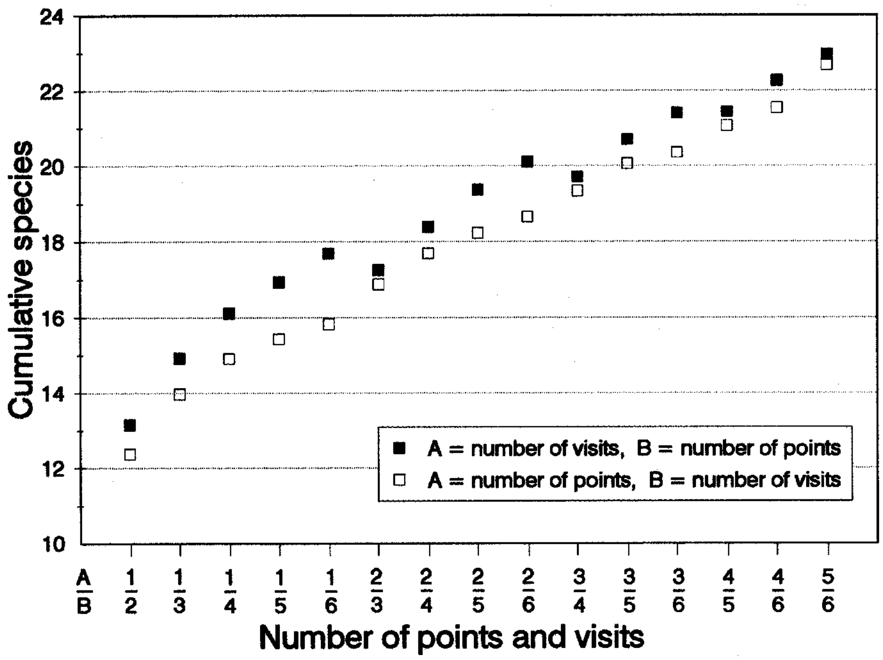

Figure 3-Comparison of cumulative number of bird species recorded between 15 possible paired reciprocals (e.g., 1 point-2 visits vs. 2 points-1 visit) of number of points visited and number of visits to each point, Delta Experimental Forest, Stoneville, Miss., 1991.

more points visited yielded significantly greater cumulative number of species than more visits to each point both in 1991 (F = 4.34, df = 15, P < 0.0001) and in 1992 (F = 4.07, df = 15, P < 0.0001). Moreover, in all individual-paired comparisons, more points visited invariably yielded more species than more visits to each point in both 1991 (*fig. 3*) and 1992 (*fig. 4*). Also, as number of points and visits approached their maximum values, increases in either had increasingly less effect on cumulative number of species recorded in 1991 (*fig. 3*) and 1992 (*fig. 4*).

Despite the suggestion that five points or four visits to each point represented sufficient sampling effort (i.e., increases beyond either level did not significantly increase total number of species), our performance relative to capturing the variation in DEF was not impressive. In both years, the maximum proportion of the total species pool (estimated by total species recorded for the entire DEF) included in our censuses (i.e., sampling efficiency) continued to increase gradually with additional points, but approached only 55 percent in 1991 and 52 percent in 1992 (*fig. 5*). Increasing revisits beyond five visits in 1991 did not improve our ability to capture more of the species pool (*fig. 6*); in 1992, a sixth visit increased the efficiency by 1.5 percent (Δp_i = 0.015). In both years, increased efficiency (Δp_i) began to decrease rapidly beyond three visits and three points.

Applications

In planning a monitoring scheme, the amount of effort (money, personnel, time) one can expend is often fixed. Often there is a tradeoff between allocation of sampling effort toward increasing the number of experimental units, which increases statistical power, or allocation of effort toward increasing the precision and accuracy of bird abundance estimates within experimental units, which decreases statistical power if overall effort remains constant. Increasing precision and accuracy can be done by visiting more points in an experimental unit or by making more visits to single points in an experimental unit.

Our results from bottomland hardwood forests suggest that, if bird abundance is to be compared among different factor levels (patch size, habitat type, silvicultural treatment), about 50 counts per factor level should be sufficient to detect most of the biologically meaningful differences. Thus, a study comparing species distribution and abundance among three forest patch-size categories would require a minimum of 150 counts (50 counts per treatment or factor level). To avoid pseudoreplication (Hurlbert 1984), an independent observation (i.e., single point count or the mean of ≥2 censuses) should be obtained from each of the 150 forest patches. Our results also suggest that up to five points should be visited per experimental unit. Increasing the number of points, rather than the number of visits to a point, is likely to be more efficient in terms of detecting new birds. After three points or visits, efficiency decreases.

Finally, another means of reducing sample size is to accept a higher probability of rejecting the null-hypothesis when it is true (i.e., accept an (α > 0.05); or accept a lower probability of rejecting the null when it is false, i.e., increase β or reduce the power of the test (Neter and Wasserman 1974). Most biologists recognize the need to report the alpha level associated with each statistical test. It is equally important to report the power of each test when the null hypothesis is not rejected (Forbes 1990). This provides the reader with explicit information regarding the likelihood that the null hypothesis was not rejected because of small sample size.

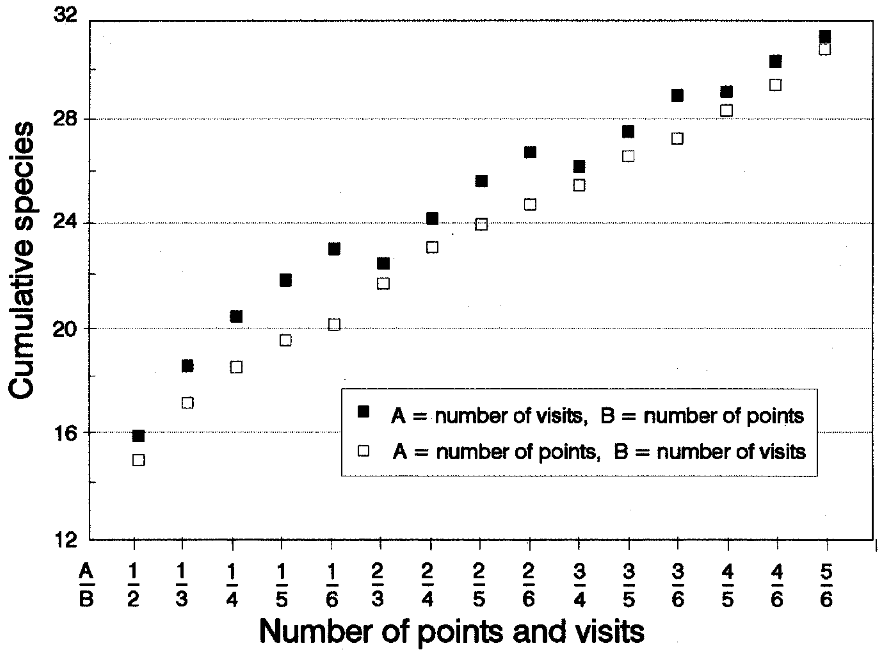

Figure 4-Comparison of cumulative number of bird species recorded between 15 possible paired reciprocals (e.g., 1 point-2 visits vs. 2 points-1 visit) of number of points visited and number of visits to each point, Delta Experimental Forest, Stoneville, Miss., 1992.

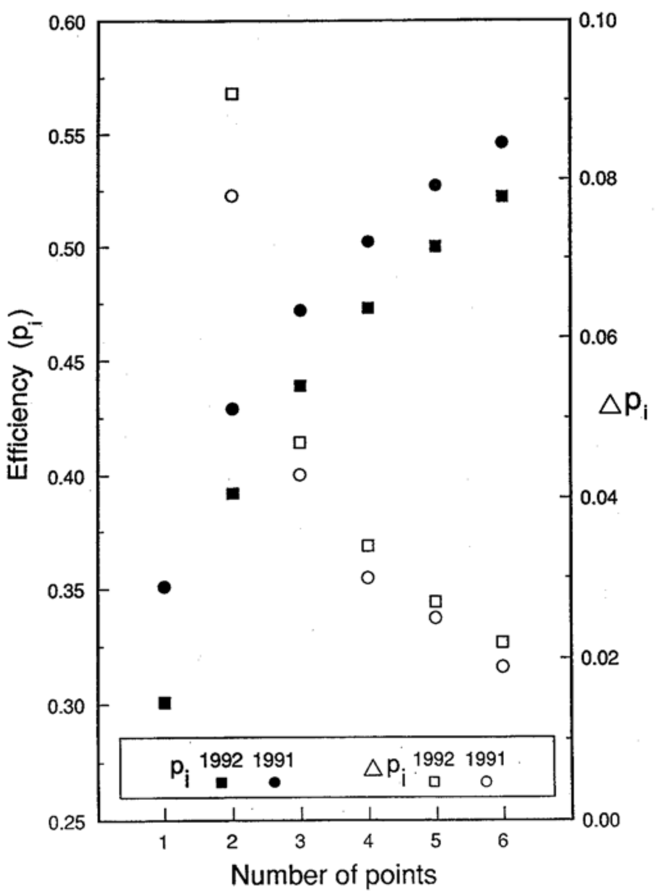

Figure 5-Proportion of 1991 and 1992 species pool included in point count censuses (EFFICIENCY, p_i) and change in efficiency (Δp_i) relative to number of points visited within a stand (averaged across all six visits), Delta Experimental Forest, Stoneville, Miss.

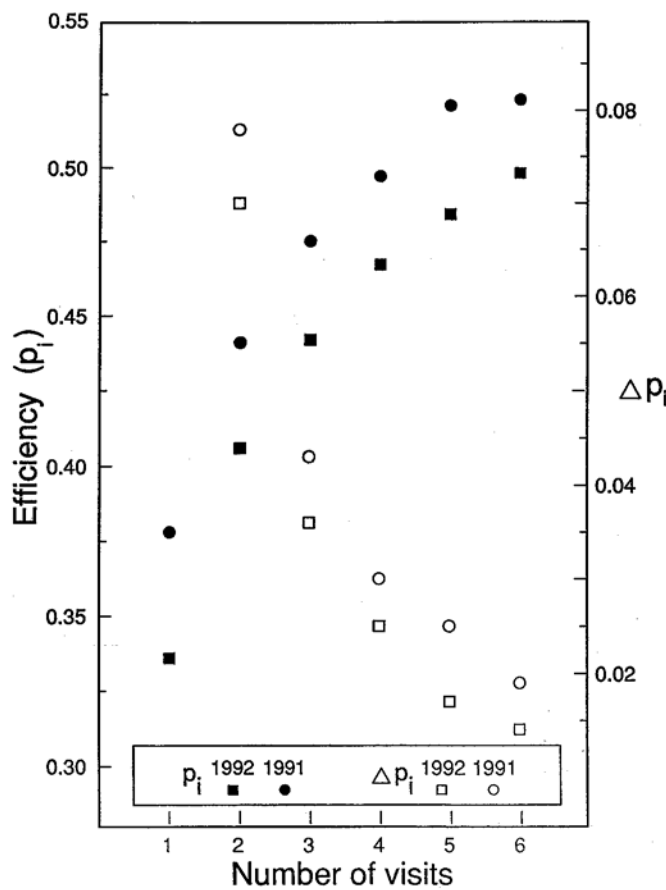

Figure 6-Proportion of 1991 and 1992 species pool included in point count censuses (EFFICIENCY, p_i) and change in efficiency (Δp_i) relative to number of visits to each point within a stand (averaged across all six points), Delta Experimental Forest, Stoneville, Miss.

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Appendix A-We calculated minimum sample size using the power method according to Neter and Wasserman (1974:492). For this paper, we selected $\alpha = 0.05$ and $\beta = 0.10$. The power of the test is given by 1-β; for this calculation, it is necessary to compute ø, the non-centrality parameter, which reflects how evenly dispersed the factor level means are relative to the overall mean. The actual factor level means were used for the calculation of "actual difference" in *table 2;* the remaining minimum sample size estimates in the table were derived using uniformly dispersed and symmetrical factor means, which minimizes the value of ø and provides the most conservative (i.e., maximizes) estimates of minimum sample size (Neter and Wasserman 1974). The formula for ø' is:

$$\phi' = \frac{1}{MSE}\sqrt{\frac{\sum(\mu_i - \mu)^2}{r}},$$

where:

ø' = estimate of the non-centrality parameter ø.
MSE = mean square error from ANOVA.
μ_i = mean for factor level *i*.
μ = overall mean.
r = number of factor levels (3, for this paper).

Once ø' has been calculated, the minimum sample size can be obtained for a specifed α and β from TABLE A-10 in the appendix tables of Neter and Wasserman (1974:827).

Appendix B-Minimum sample sizes for point counts of selected species in the lower Mississippi Alluvial Valley. Sample size was computed with the power method for α. = 0.05 and β = 0.10 with several detectable difference values among factor level means.

			Sample Size Required for		
Species	MSE[1]	Mean[2]	Actual Difference[3]	±0.25 Birds[4]	±25 percent of mean[5]
Acadian Flycatcher+					
Region	0.59	0.915	53	65	80
Southern	0.89	1.038	>200	95	90
Central	0.22	0.607	9	23	65
Northern	0.58	1.107	>200	65	50
Habitat	0.62	0.915	>200	70	85
American Redstart					
Region	0.02	0.024	>200	9	>200
Southern	0.04	0.038	65	9	>200
Central	0.03	0.036	53	9	>200
Northern	0.00	0.000	>200	>200	>200
Habitat	0.02	0.024	>200	9	>200
Blue-gray Gnatcatcher+					
Region	0.55	0.744	9	58	100
Southern	0.41	0.308	>200	44	>200
Central	0.39	0.429	44	44	>200
Northern	0.91	1.464	>200	95	44
Habitat	0.83	0.744	>200	90	>200
Brown-headed Cowbird					
Region	0.43	0.415	23	44	>200
Southern	0.00	0.000	>200	>200	>200
Central	0.78	0.750	50	85	>200
Northern	0.45	0.464	33	44	>200
Habitat	0.48	0.415	44	50	>200
Carolina Chickadee+					
Region	1.16	0.805	85	>200	>200
Southern	2.32	1.077	>200	>200	>200
Central	1.91	0.893	>200	>200	>200
Northern	2.58	0.464	>200	>200	>200
Habitat	1.22	0.805	>200	>200	>200
Carolina Wren+					
Region	0.76	1.402	>200	85	44
Southern	0.77	1.615	>200	85	33
Central	0.78	1.357	19	85	44
Northern	0.67	1.250	>200	80	44
Habitat	0.64	1.402	23	70	33
Hooded Warbler					
Region	0.08	0.098	65	9	>200
Southern	0.15	0.192	33	15	>200
Central	0.00	0.000	>200	>200	>200
Northern	0.11	0.107	>200	9	>200
Habitat	0.09	0.098	>200	9	>200
Indigo Bunting					
Region	0.19	0.110	50	19	>200
Southern	0.00	0.000	>200	>200	>200
Central	0.04	0.036	58	9	>200
Northern	0.51	0.286	65	53	>200
Habitat	0.18	0.110	33	19	>200

continued

Appendix B-*continued*

Species	MSE[1]	Mean[2]	Sample Size Required for: Actual difference[3]	±0.25 birds[4]	±25 percent of mean[5]
Kentucky Warbler					
Region	0.09	0.110	80	9	>200
Southern	0.07	0.077	27	9	>200
Central	0.03	0.036	44	9	>200
Northern	0.18	0.214	>200	19	>200
Habitat	0.09	0.110	23	9	>200
Northern Cardinal+					
Region	1.29	1.585	>200	>200	53
Southern	0.91	1.769	9	95	33
Central	1.14	1.714	27	>200	44
Northern	0.85	1.286	>200	90	53
Habitat	1.33	1.585	>200	>200	53
Northern Parula					
Region	0.22	0.220	27	23	>200
Southern	0.22	0.462	9	23	>200
Central	0.24	0.214	9	27	>200
Northern	0.00	0.000	>200	>200	>200
Habitat	0.25	0.219	>200	27	>200
Prothonotary Warbler+					
Region	0.56	0.951	9	58	70
Locality					
Southern	0.74	1.885	53	85	23
Central	0.57	0.571	>200	58	>200
Northern	0.32	0.464	15	33	>200
Habitat	0.82	0.951	23	90	95
Red-bellied Woodpecker+					
Region	0.82	1.256	>200	90	53
Southern	0.37	1.115	9	37	33
Central	0.66	1.143	85	70	53
Northern	0.92	1.500	29	95	44
Habitat	0.82	1.256	100	90	53
Red-eyed Vireo					
Region	0.36	0.524	15	37	>200
Southern	0.50	1.038	44	53	50
Central	0.21	0.321	9	23	>200
Northern	0.24	0.250	23	27	>200
Habitat	0.44	0.524	44	44	>200
Rufous-sided Towhee					
Region	0.02	0.024	>200	9	>200
Southern	0.04	0.038	65	9	>200
Central	0.04	0.036	58	9	>200
Northern	0.00	0.000	>200	>200	>200
Habitat	0.02	0.024	58	9	>200
Summer Tanager					
Region	0.25	0.244	53	27	>200
Southern	0.04	0.038	65	9	>200
Central	0.38	0.321	15	37	>200
Northern	0.25	0.357	>200	27	>200
Habitat	0.26	0.244	>200	27	>200

continued

Appendix **B--*continued***

Species	MSE[1]	Mean[2]	Sample Size Required for: Actual difference[3]	±0.25 birds[4]	±25 percent of mean[5]
Tufted Titmouse+					
Region	0.52	0.878	58	53	80
Southern	0.47	0.615	15	50	>200
Central	0.44	0.893	15	44	58
Northern	0.45	1.107	33	44	37
Habitat	0.56	0.878	>200	58	85
Wood Thrush					
Region	0.23	0.232	>200	27	>200
Southern	0.32	0.308	>200	33	>200
Central	0.15	0.179	58	15	>200
Northern	0.26	0.214	>200	27	>200
Habitat	0.23	0.232	>200	27	>200
Yellow-billed Cuckoo					
Region	0.43	0.659	80	44	100
Southern	0.45	0.885	>200	44	65
Central	0.36	0.607	27	37	100
Northern	0.42	0.500	23	44	>200
Habitat	0.45	0.659	>200	44	>200
Yellow-throated Vireo					
Region	0.05	0.049	100	9	>200
Southern	0.00	0.000	>200	>200	>200
Central	0.10	0.107	37	9	>200
Northern	0.04	0.036	80	9	>200
Habitat	0.05	0.049	>200	9	>200

[1] Mean Square Error of one-way Analysis of Variance, with three levels of treatment (for example, northern, central and southern region).

[2] Mean birds or species per count. This value is the same for Region and Habitat.

[3] Sample size that is required to get statistical significance for the actual observed difference among factor level means (range). Note that the minimum sample sizes in *appendix B* were all calculated using a design with one factor and three factor levels. If more or fewer levels were used, this number would be slightly greater or smaller; however, the numbers in *table 2* are a useful approximation.

[4] Sample size that would be required to detect a significant difference of 0.25 birds or 0.25 species above or below the overall mean.

[5] Sample size that would be required to detect a significant difference between two treatments that is between 25 percent above and 25 percent below the overall mean (that is, the difference between two treatment means of 50 percent of the overall mean).

\+ denotes the most abundant species, i.e., those whose totals comprised >50 percent (872/1621) of all birds recorded during point counts conducted throughout the lower Mississippi Alluvial Valley, May 7-16, 1992.