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Point Counts Of Birds in Bottomland Hardwood Forests of the Mississippi Alluvial Valley: Duration, Minimum Sample Size, and Points Versus Visits

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SUMMARY

To compare efficacy of point count sampling in bottomland hardwood forests, duration of point count, number of point counts, number of visits to each point during a breeding season, and minimum sample size were examined. Minimum sample sizes were computed from the variation recorded during 82 point counts from 3 selected localities containing 3 habitat types (wet, mesic, and dry) across 3 regions of the Mississippi Alluvial Valley (northern, central, and southern). For each of these point counts, all birds seen or heard during the initial 3 minutes and during each minute thereafter up to 10 minutes within three concentric distance categories (<25 m, 25 to 50 m, and >50 m) were recorded. In a second study, the effect of increasing the number of points or visits was determined by comparing the results of 150 4-minute point counts obtained from each of four stands on Delta Experimental Forest. Within each stand, bootstrap estimates of the mean cumulative number of species each year were obtained from all possible combinations of six points and six visits. Similar analyses of 384 counts obtained from 132 points distributed among 56 sites in west Tennessee bottomland forests were undertaken. Mean number of species recorded during 5- and 10-minute counts were 10.3 and 12.9 and 11.3 and 14.7 for the lower MAV and west Tennessee, respectively. There was significant variation in numbers of birds and species between regions and localities nested within regions; neither habitat nor the interaction between region and habitat was significant. Sample size sufficient to detect actual differences of some species (e.g., wood thrush *(Hylocichla mustelina)*) was >500; for other species (e.g., prothonotary warbler *(Protonotaria citrea)*), this same level of precision could be achieved with <10 counts. Significant differences in mean cumulative species were detected among the number of points visited and among the number of visits to a point. Although no interaction was detected between number of points and number of visits, when paired reciprocals were compared, more points invariably yielded significantly greater cumulative number of species than more visits to a point in the lower MAV. In west Tennessee, more points yielded either similar or significantly more cumulative species than more visits.

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INTRODUCTION

Recently there has been much interest regarding apparent declines of bird species that were historically resident or breeding in bottomland hardwood forests of the lower Mississippi River Valley. Previous investigators, notably Burdick and others (1989) and Wiedenfeld and others,[1] demonstrated appreciable and consistent declines of many species within the Mississippi Alluvial Valley (MAV). In particular, numerous neotropical migrant bird (NTMB) species have experienced significant declines over the last two decades, many of which appeared to increase in other portions of their historical ranges.[1] As a result of this concern, university scientists, personnel of Federal and State natural resource agencies and nongovernmental organizations, and public and private land managers are initiating research or other monitoring programs with the specific goal of quantitatively describing NTMB species distributions and relative abundance among the remaining forest fragments.

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 has not been achieved. The Monitoring Working Group of the Neotropical Migrant Bird Conservation Program has recently released a recommended protocol for sampling bird populations (Ralph and others, in press). The intent was to provide guidelines that woul facilitate obtaining bird population data in a standardized and consistent fashion across North America However, habitat features vary substantially withi and among forest types. Moreover, research needs o management goals vary within, as well as across regions, and a single protocol for all situations is unwieldy. It is important, nonetheless, that research a other monitoring programs use a sampling desig that is fundamentally compatible with the recommended protocol of the Monitoring Working Group s that data are comparable. That is, additional dat may be collected to meet specific research goals, bu where possible, the basic information prescribed b the Monitoring Working Group should be include within the framework of all future investigations.

The purpose of this research was to evaluate the e ficacy of point count surveys in bottomland hardwoc forests. Specific objectives were to determine: (whether the recommended. distance measures f point count circular plots are useful in bottomlar hardwood forests, (2) the optimum duration for ea point count, (3) the optimum number of points sample at each locality, (4) the optimum number counts at each point during a season, and (5) the mi imum sample size to accommodate the variation bird species distribution and relative abundan throughout the lower MAV.

METHODS

Study Areas

For this paper, data from three similar studies we compiled, the most recent of which was designed address questions related to estimating duration a

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[1] Wiedenfeld, David A.; Messick, Lyla A.; James, Frances C. 1992. Population trends in 65 species of North American birds 1965-1992. 200 p. Unpublished report to National Fish and Wildlife Foundation, U.S. Department of the Interior Fish and Wildlife Service, and U.S. Department of Agriculture, Forest Service. On file with: National Wildlife Foundation, 1400 Sixteenth Street NW, Washington, DC 20036-2266.

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sample size of point counts sufficient to detect meaningful biological differences at different spatial scales and levels of resolution. To estimate variability throughout the lower MAV, a balanced study design that included three point counts at each of three localities within each of three habitats (wet, mesic, and dry) was developed. This sampling design was repeated in each of 3 regions (southern, central, and northern) of the lower MAV (i.e., 3 x 3 x 3 x 3) for a total of 81 point counts (fig. 1). Wet habitat sites were characterized by cypress (*Taxodium* spp.) or tupelo (*Nyssa* spp.). Mesic habitat sites were seasonally flooded, lowland flatwoods, and dry habitat sites were ridges or rarely inundated bottomland forests. Forest tracts on public lands were selected primarily because of dependable access. Each locality was 240 ha to accommodate three points that were at least 250 m apart (Ralph and others, in press) and 2200 m from the forest edge.

In addition, point counts from a 3-year study (1985–87) in west Tennessee boitomlands, i.e., from the Tennessee River west to the Mississippi River, were included (Durham and others 1988, Ford 1990). Sites were randomly chosen, but stratified among the seven major drainages in west Tennessee: Wolf, Loosahatchie, Hatchie, Forked Deer, Obion, Tennessee, and Mississippi Rivers. Each drainage was allotted a minimum of 10 percent of the sites. Within the Tennessee River drainage, three of the six major tributaries were randomly selected: White Oak Creek, Birdsong Creek, and Big Sandy River. Each site was ≥40 ha of relatively homogeneous bottomland hardwood forest. Ford (1990) provides a detailed description of study sites and selection procedures.

Delta Experimental Forest (DEF) (fig. 1), Stoneville, MS, was the site of a 2-year study (1991-92) examining the influence of forest management on breeding bird density and diversity,[2] DEF encompasses about 1,050 ha and represents one of the few remaining large (≥500 ha), contiguous, bottomland forests within a 100-km radius of Stoneville. Delta Experimental Forest was initially logged during the early 20th century and selectively logged until 1939 (Delta Council 1945).

Point Count Protocol

With few exceptions, general guidelines and proce dures for point count censusing of birds (Ralph an others, in press) were followed. For each of th separate studies, however, a brief description of spe cific features that were fundamental departures fror their recommended protocol was provided. The poir counts within the lower MAV was of lo-minute dura tion and occurred during the first 4 hours after daw

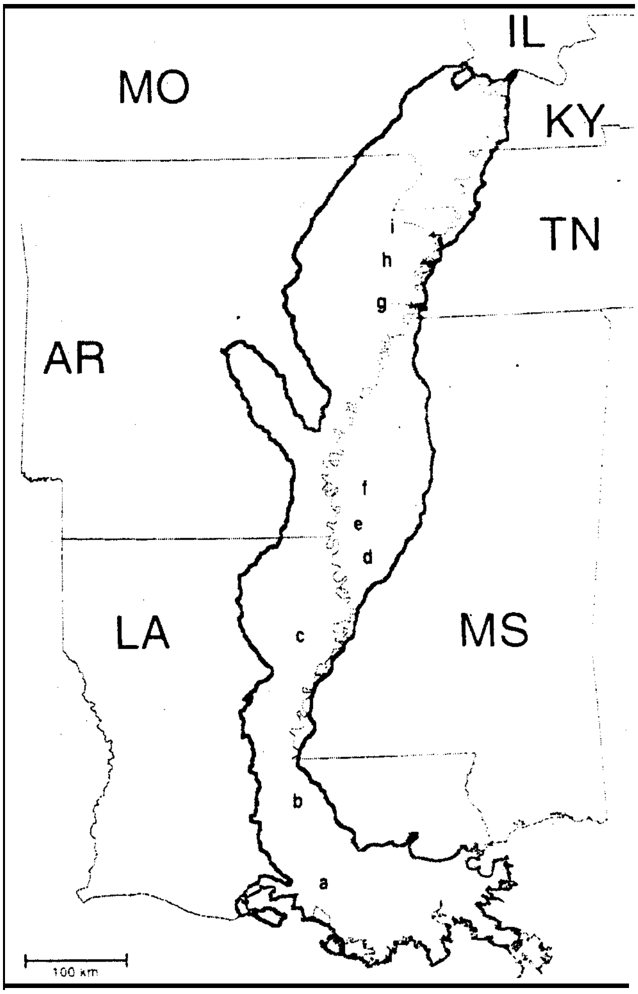

Figure 1.—*Location of point count sites within the southern, centr and northern regions of the lower Mississippi Alluvi Valley (enclosed area) and west Tennessee bottomlan (g,h,i): southern- a. Lake Fausse Pointe State Park, Sherburne wildlife Management Area (two localitie central- c. Tensas River National Wildlife Refu (NWR), d. Panther Swamp NWR, e. Yazoo NWR; nort ern- f. Delta Experimental Forest, Stoneville, M g. Meeman-Shelby Forest, State Park and Wildl Management Area, h. Lower Hatchie NWR, i. Chic asaw NWR. Not shown: portions of Mississippi River luvial Plain extending upstream along later tributaries.*

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[2] Smith, Winston Paul. 1991. Wildlife use of bottomland hardwoods 50 years after timber stand improvement or clearcutting: I. Density and species composition of the breeding and wintering avifauna. Study Plan No. FS-SO-4101-91. On file with: U.S. Department of Agriculture. Forest Service, Southern Forest Experiment Station, Stoneville, MS.

(i.e., before 10 a.m. CDT). Each point was visited once during 7 through 16 May 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 to 50 m, or >50 m. When necessary, the rangefinder was used to verify distance. Only birds that were observed using the forest patch were included in the sample. This excluded several species that typically flew over forest patches, such as swifts, swallows, herons, and egrets.

Within the west Tennessee bottomlands, point counts were obtained from 132 points distributed among 56 forest tracts. In 1985 and 1986, point counts were conducted during an 8-week period, which began in early May and continued into early July; in 1987, point counts occurred during a 4-week period beginning in late May. Each point was visited from one to four times in 2 of the 3 years; no point was visited more than twice each year. A point count consisted of recording the number of all birds seen or heard (including birds that flew over the point) during each of four, consecutive B-minute periods. Censuses usually were completed during the 4-hour period following sunrise (Durham and others 1988, Ford 1990).

On DEF, 25 points were established within each of 4 stands, 2 silvicultural treatments, and a paired control for each treatment. One treatment was a 1937 clearcut that naturally regenerated; the second underwent timber stand improvement cuts in 1937. Each control had not been managed since the last high-grade harvest in the mid-1930's.

Within each stand, each point was systematically sampled five to seven times during the 3-hour period following sunrise from 8 to 21 May 1991, and from 30 May to 12 June 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 per minute for a total of 4 minutes.

Common names follow the sixth edition of the checklist of North American birds (American Ornithologists' Union 1983).

Data Analyses

Point Count Duration.-For both the lower MAV and west Tennessee bottomlands, mean cumulative number of individuals and mean cumulative number of species were plotted against point count duration to examine whether total individuals or species approached an asymptote during the sampling period. In addition, general regression (REG Procedure; SAS Institute, Inc. 1988, p. 773) was used to derive linear regression models of number of new individuals or number of new species encountered within each time interval, as a function of duration of point count for 1985, 1986, and 1987 censuses in west Tennessee. An analysis of covariance (Zar 1984, p. 300) was used to determine whether the slopes of corresponding linear models (i.e., individuals or species) differed among years. For this paper, efficiency was quantified as number of new birds or species per unit effort.

Point Count Variation and Minimum Sample Size.-A Chi-square test of independence was used to examine whether the number of birds recorded in each distance category was independent of habitat (i.e., 3 x 3 contingency table); subdividing Chi-square analysis (Zar 1984, p. 69) determined where significant departures occurred. For west Tennessee censuses, three-dimensional contingency table analyses determined whether frequency distribution of detected birds among distance categories differed among years or between 10- and 20-minute point counts (Zar, 1984, p. 72). Analysis of variance (ANOVA) (GLM Procedure; SAS Institute, Inc. 1988, p. 549) was used to determine whether significant variation in number of individuals or species counts occurred among regions, habitats, or localities (nested within region), or through interaction of region and habitat.

Calculation of minimum sample size followed Neter and Wasserman (1974, p. 492) for a specified a, β, number of factors and ϕ. Specifying ϕ, the noncentrality parameter, requires determining how much factor level means (e.g., regions) must differ to represent a statistical difference (Neter and Wasserman 1974). For this paper, three different specifications were selected for ϕ. 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 red-eyed vireos [*Vireo olivaceus*] among habitats) was used to calculate ϕ. The other two specifications were arbitrary, but represent extremes with respect to resolution. Sample sizes for a difference of ± 0.25 are those that would be required to detect statistical significance if the greatest difference among factor levels was 0.25 birds or 0.25 species. These estimates could be used for investigations focusing on endangered species or threatened communities requiring monitoring protocols sensitive to relatively small changes. Our final ϕ value was based on a precision of ± 25 percent of the mean; this corresponds logically with 0.25 birds or species but represents a coarser filter for investigating differences in species distribution and abundance. Large-scale monitoring programs would perhaps use this level of precision as an indication of local or regional changes.

Comparison of Duration, Number of Points, and Number of Visits.-A matrix of mean cumulative number of species for censuses with all possible combinations of six points and six visits was generated using the bootstrap procedure (Efron 1982). Within each stand, observations for each combination (e.g., 2 visits to each of 4 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, whereas successive visits were randomly selected. Each mean value was computed from 250 resampling iterations and represented an independent observation of a point times visit combination within the selected stand.

A similar procedure involving 50 resampling iterations of a bootstrapping procedure was used to generate an array of mean number of cumulative species for all possible combinations of one to four visits of varying duration (5 to 20 minutes) to each of three points from all suitable point counts (1985–87) in west Tennessee. As before, cumulative number of species recorded between counts that represented varying number of points and visits to each point were compared. In addition, mean cumulative number of species were compared for combinations of censuses that represented equivalent effort but could be applied as either a single count, or recorded among multiple points or over multiple visits. For example, a 20-minute census could be conducted as four consecutive 5-minute counts at the same point, or as four separate 5-minute counts conducted at a single point; as two separate 10-minute counts at a single point; or as single 10-minute counts at two separate points.

Analysis of variance (GLM Procedure; SAS Institute, Inc. 1988, p. 549) was conducted 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. For west Tennessee censuses, the General Linear Model (GLM) procedure included an analysis of point count duration and its interaction with number of points or number of visits for counts of cumulative duration of 20 minutes. Scheffe's multiple comparison procedure was performed to determine which main effect means differed. An a priori simultaneous comparison was conducted using a contrast statement within the ANOVA (SAS Institute, Inc. 1988, p. 560) to compare the 15 possible reciprocal combinations of points and visits that were conducted on DEF.

RESULTS AND DISCUSSION

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), all 3 types of habitat were not found in all localities. The dry habitat was not identified at either Lake Fausse Pointe State Park or Area 2 in Sherburne Wildlife Management Area, and wet habitat was not located within Tensas River National Wildlife Refuge. During the period 7 May through 16 May 1992, 82 10-minute point counts were completed (table 1).

Within the lower MAV, 1,621 individual birds distributed among 52 species were recorded. The majority of individuals (872) were represented by 8 species. The maximum number of individuals recorded during any single 10-minute count was 32, whereas the minimum was 11; the average was 19.8 birds per count (table 2). The number of species recorded varied from 9 to 18 with an average of 12.9 species per count (table 2).

In west Tennessee bottomlands, 195, 144, and 45 point counts were conducted in 1985, 1986, and 1987, respectively. Overall, 12,471 individuals and 79 species were recorded. The number of individuals recorded during any 20-minute census varied from 11 to 74 and averaged 32.48 (table 2). The number of species recorded varied from 7 to 38 with an average of 19.09 species per census (table 2).

Table 1.-*Locations and number of point counts for bird censuses conducted within the Lower Mississippi Alluvial Valley, 7 through 16 May 1992*

	Type of habitat		
Site	Wet	Mesic	Dry
	............*Number*............		
Southern region			
Lake Fausse Pointe State Park, Louisiana	4	4	0
Sherburne Wildlife Management Area, Louisiana, Area 1	5	1	3
Sherburne Wildlife Management Area, Louisiana, Area 2	5	4	0
Central region			
Tensas River National Wildlife Refuge, Louisiana	0	4	5
Yazoo National Wildlife Refuge, Mississippi	2	3	3
Panther Swamp National Wildlife Refuge, Mississippi	5	2	4
Northern region			
Meeman-Shelby State Forest, Tennessee	3	3	3
Chickasaw National Wildlife Refuge, Tennessee	3	3	3
Lower Hatchie National Wildlife Refuge, Tennessee	4	4	2
Total	31	28	23

Table 2.—Mean standard error (SE), and minimum and maximum numbers (range) of individual birds and species recorded during point counts of 5-, 10-, 15-, and 20-minute duration in each year and overall from 1985 to 1987 in west Tennessee bottomlands and during point counts of 5- and lo-minute duration from 1991 to 1992 throughout the lower Mississippi Alluvial Valley

Location/year	Duration of point count											
	5 minutes			10 minutes			15 minutes			20 minutes		
	Mean	SE	Range	Mean	SE	Range	Mean	SE	Range	Mean	SE	Range
	Number of individuals											
West Tennessee bottomlands												
1985	12.9	0.281	5-31	18.7	0.332	8-34	23.4	0.382	9-50	28.7	0.412	17-74
1986	17.2	0.440	0-30	24.9	0.588	15-42	30.3	0.684	1-50	36.4	0.787	23-57
1987	19.2	0.647	7-29	26.8	0.831	9-36	32.2	1.017	11-48	36.1	1.136	11-52
1985-87	15.3	0.262	o-31	22.0	0.340	8-42	27.0	0.391	1-50	32.5	0.431	11-74
Lower Mississippi Alluvial Valley												
1991-92	15.0	0.041	7-27	19.8	0.444	11-32	*	*	*	*	3	*
	Number of species											
West Tennessee bottomlands												
1985	10.1	0.179	3-17	13.4	0.203	5-20	15.9	0.213	6-23	18.2	0.214	7-38
1986	12.7	0.245	0-20	16.2	0.327	10-24	18.1	0.374	1-29	20.3	0.422	13-31
1987	12.5	0.409	6-17	15.8	0.482	7-21	17.9	0.481	8-25	19.1	0.482	8-25
1985-87	11.3	0.152	0-20	14.7	0.182	5-24	17.0	0.193	1-29	19.1	0.206	7-38
Lower Mississippi Alluvial Valley												
1991-92	10.3	0.025	6-16	12.9	0.257	9-18	*	*	*	*	*	*

*No data available.

Duration of Point Counts

One of our stated objectives was to determine the most efficient point count interval, which has been variously recommended as 3 minutes (e.g., U.S. Department of the Interior 1990), 5 minutes,[3] 4 or 8 minutes (Anderson and Ohmart 1981), or even 20 minutes (Blondel and others 1970). Cumulative number of new individuals and of new species encountered per minute in the lower MAV were plotted (fig. 2). Both the number of new individuals and new species continued to increase throughout the lo-minute census (fig. 2). In west Tennessee bottomlands, neither the cumulative number of birds (fig. 3a) nor species (fig. 3b) approached an asymptote even after 20 minutes. Moreover, mean cumulative number of species differed among censuses of varying lengths ($F = 322.7$, df = 3, $P < 0.001$); cumulative number of species increased with each additional 5 minutes of sampling ($F = 23.80$, df = 945, $P \leq 0.01$). However, the relationship between numbers of new birds or species relative to sampling effort appeared similar across years. The slopes of the regressions of number of new species as a

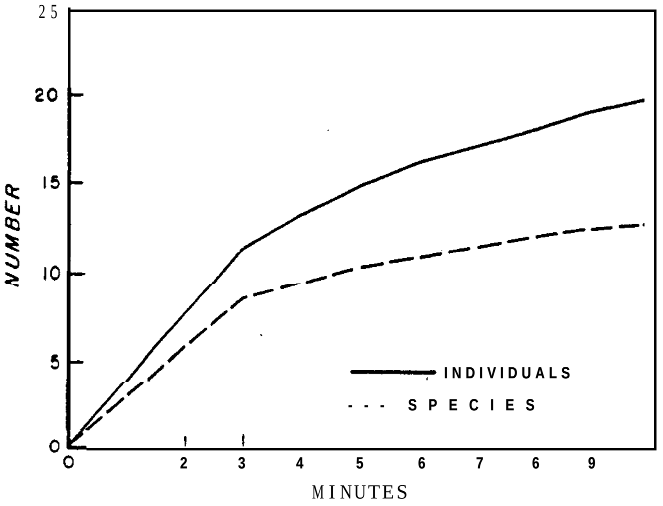

Figure *P.-Cumulative number of new individual birds and cumulative number of new bird species recorded per minute during 82 -IO-minute point counts conducted throughout the lower Mississippi Alluvial Valley, 7 May through 16 May 1992.*

“Ralph, C. John; Droege, Sam: Sauer, John R. 1992. Managing and monitoring birds using point counts: standards and applications. Unpublished report of the Monitoring Working Group, Neotropical Migrant Bird Conservation Program. 12 p. On file with: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station, RWU-4251, Redwood Sciences Laboratory, Arcata, CA 95521.

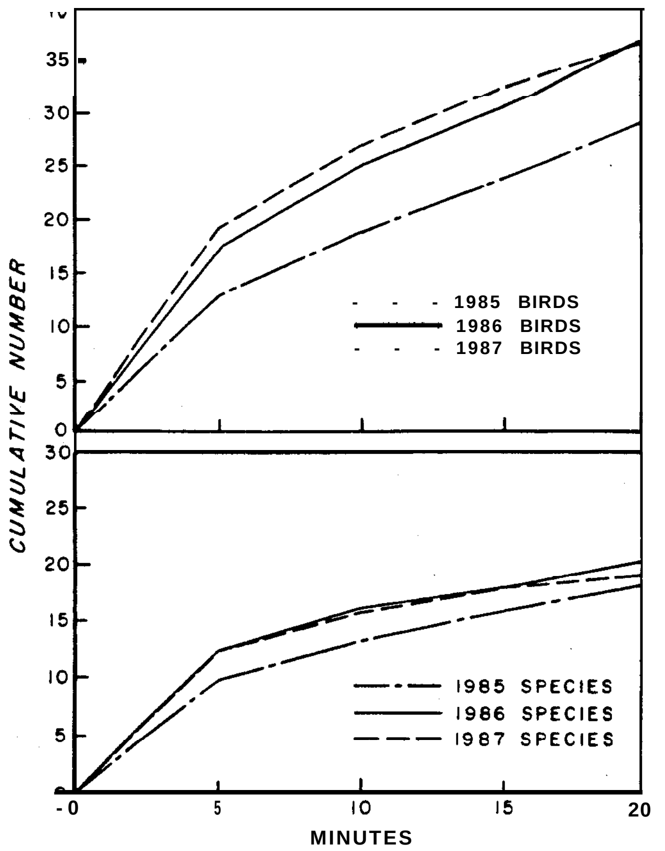

Figure 3.—*Cumulative number of breeding birds (a) and cumulative number of bird species (b) recorded per 5-minute interval during 20-minute point counts conducted among seven major drainages of west Tennessee in 1985, 1986, and 1987.*

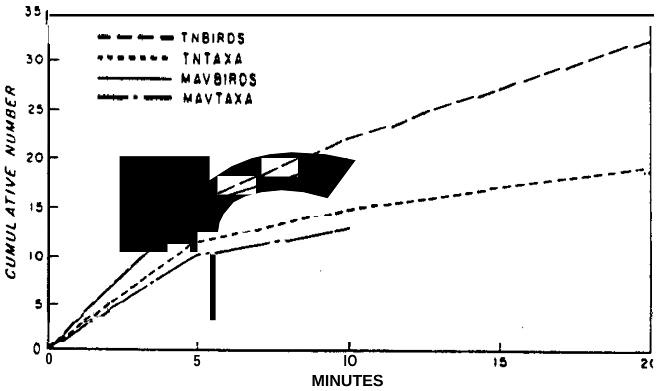

Figure 4.-*Overall average (1985-87) of cumulative number of breeding birds (TNBIRDS) and cumulative number of bird species (TNTAXA) recorded in west Tennessee bottomlands and cumulative number of all birds (MAVBIRDS) and bird species (MAVTAXA) including migrating birds recorded in the lower Mississippi Alluvial Valley, 7 May through 16 May 1992.*

function of elapsed time did not differ among years ($F = 0.836$; $df = 2,6$; $P > 0.5$). This was true also for number of new birds ($F = 0.520$; df = 2,6; $P > 0.5$). In addition, plots of cumulative number of individuals and species from the lower MAV appeared to behave in a similar fashion to their west Tennessee counterparts (fig. 4).

Apparently, longer censuses would be required to count all (or even most) of the individuals or species in bottomland hardwood forests. Extending counting periods, however, increases the likelihood of repeated counts of the same individual because birds move or because the observer forgets where birds were initially recorded (Scott and Ramsey 1981). This duplication would only influence density estimates, however, because new species are necessarily recognized as unique during each point count. Still, point counts of longer duration may not be the most efficient means of sampling avifauna. The results of our study indicate that point counts of much longer duration than 20 minutes may be necessary to even approach the total number of species. Although prolonged censuses may be a viable option for researchers, constraints of personnel, time, and other responsibilities preclude public or private land managers from implementing a point count protocol that requires excessively long counts at one point, particularly in light of site and regional variability (see Minimum Sample Size) in bottomland hardwood forests.

An alternative approach might be to determine an acceptable percentage of the available avifauna to be included in a sample and to determine the point count interval that consistently includes this proportion. For example, 80 percent of the species (845/1045) and about 75 percent of the individuals (1,226/1,621) encountered during an entire lo-minute point count in the lower MAV were recorded within the initial 5-minute period. Corresponding percentages for west Tennessee (i.e., total species and total birds recorded within the initial 5-minute interval relative to a 10-minute interval) were similar (77 percent and 70 percent, respectively) to the lower MAV. However, when one compares the number of birds and species recorded in a 5-minute census to the totals obtained from 20-minute point counts, the percentages are appreciably lower (59 percent and 47 percent, respectively). Thus, to use this approach one needs to conduct point counts of sufficient duration to observe or predict a marked downward inflection in the curve of birds or species recorded per unit effort. To obtain “asymptotic estimates” may require preliminary censuses that approach or even exceed 40 minutes. However, once the relationship between acceptable proportion of total individuals or species and point count duration has been derived, our data suggest that expected percentages within samples of specified dura-

Table 3.—Mean cumulative number of individual birds and species predicted from power function regression equations for lower Mississippi Alluvial Valley (MAV) (birds = 7.098 x $(minutes)^{0.4508}$, R^2 = 0.995: *species = 5.867 x* $(minutes)^{0.3460}$, R^2 = *0.9981, and west Tennessee bottomlands (birds = 6.53 x* $(minutes)^{0.5144}$, R^2 = *0.993; species = 6.23 x* $(minutes)^{0.3742}$, R^2 = 0.999)

Time intervals	Lower MAV		West Tennessee bottomlands	
Minutes	*Mean number of individuals*	*Mean number of species*	*Mean number of individuals*	*Mean number of species*
5	14.7 (15.0)*	10.2 (10.3)	14.9 (15.3)	11.4 (11.3)
10	20.0 (19.8)	13.0 (12.9)	21.4 (22.0)	14.8 (14.7)
20	27.4	16.5	30.5 (32.5)	19.1 (19.1)
30	32.9	19.0	37.6	22.2
40	37.4	21.0	43.6	24.8
50	41.4	22.7	48.8	26.9
60	45.0	24.2	53.6	28.8
80	51.2	26.7	62.2	32.1

*Observed means are given in parentheses.

tion should not vary among years or even among regions. (Recall that the regression slopes of cumulative species or cumulative birds were similar among years and among regions.)

To examine the feasibility of predicting the most efficient time interval for point counts, a power function regression curve was fitted to the cumulative number of individuals and to the cumulative number of species recorded in the lower MAV as a function of point count duration. Variation in both number of birds (Y = 7.098 multiplied by $(minutes)^{0.4508}$, R^2 = 0.995) and number of species (Y = 5.867 multiplied by $(minutes)^{0.3460}$, R^2 = 0.998) was almost completely explained by the derived regression equations. For west Tennessee bottomlands, comparable power function relationships were observed for cumulative number of birds (Y = 6.53 multiplied by $(minutes)^{0.5144}$, R^2 = 0.953) and cumulative number of species (Y = 6.23 multiplied by $(minutes)^{0.3742}$, R^2 = 0.999). Using the respective power function equations, cumulative number of individuals or species that would be recorded during point counts of up to 80 minutes were predicted (table 3).

The number of birds and species recorded during 5-minute censuses were compared to that predicted from a wide range of point count intervals. For example, 5-minute counts from west Tennessee (table 3) included 35 percent of the birds and 46 percent of the species predicted for 40-minute censuses. (Recall that 5-minute censuses included 47 percent of the birds and 59 percent of species recorded in 20-minute counts.) Corresponding percentages for the lower MAV were 40 percent and 49 percent. Thus, a two-fold increase in sampling effort (40 minutes vs. 20 minutes) in west Tennessee reduced the percentages included in a 5-minute census by a factor of 0.3 for birds [(47 percent • 35 percent)/35 percent] and for species [(59 percent - 46 percent)/46 percent]. Corresponding rates of reduction for 5-minute counts in the lower MAV were 0.4 and 0.3, suggesting that the expected benefit derived from longer censuses is much less than proportional to the increased effort.

This reduction was illustrated more clearly when efficiency (i.e., predicted increase in new birds or new species per unit effort) of point counts of varying duration was examined (fig. 5). On the average, lower MAV and west Tennessee point counts added 3.0 new birds and 2.2 new species per minute during a 5-minute census. Efficiency was markedly lower for both number of new birds and number of new species beyond 5 minutes, however, decreasing by as much as 73 percent (range from 56 to 73 percent) and averaging 66 percent. Except for lo-minute counts (i.e., new birds and new species added between 5 and 10 minutes) in west Tennessee, efficiency was below one new bird or one new species per minute for all point count intervals beyond 5 minutes (fig. 5). Efficiency gradually declined beyond 10 minutes until it essentially reached a negative asymptote ‘at 40 minutes (fig. 5).

To evaluate further the proposed 5-minute point count protocol of Ralph and others (in press), all subsequent analyses of bird censuses from the lower MAV were restricted to species or individuals recorded during the’first 5 minutes of each point count. Unless otherwise noted, subsequent analysis of west

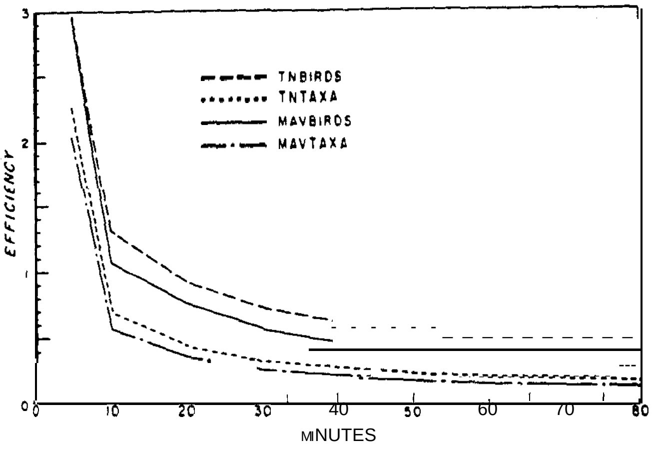

Figure 5.—*Efficiency, i.e., number of new birds (TNBIRDS, MAVBIRDS) or bird species (TNTAXA, MAVTAXA) recorded per minute, of point counts of varying duration within hardwood forests of the lower Mississippi Alluvial Valley (MAV), 1992, and west Tennessee bottomlands (TN), 1985-1987.*

Tennessee data included cumulative number of birds and cumulative number of species recorded in each 20-minute census.

Radius Distance of Plots

In the lower MAV study, distance to each bird was recorded as either <25 m, between 25 and 50 m, or >50 m (table 4). By inspection, it appeared that more birds were recorded in the intermediate distance category (521) than in the closest category (340) or farthest category (365). The observed frequency distribution, however, did not depart significantly from a null proportional distribution across distance categories and among habitats ($X^2 = 8.90$, df = 4, $P = 0.064$) The proportion of birds recorded in each of the distance categories was somewhat surprising because the closest concentric ring represented a much smaller area (1,964 m^2) than the second (5,890 m^2), or the outer category (23,562 m^2, assuming a maximum detectable distance of 100 m). Accordingly, the percentage of birds recorded within each of the categories should have increased with area, i.e., distance from the observer.

When the observed distribution was compared to a frequency distribution determined according to total area sampled, there was a highly significant departure from the expected ($X^2 = 1{,}313$, df = 6, $P < 0.001$). There were significantly more birds ($X^2 = 562$, df = 2, $P < 0.001$) observed within 25 m than expected (101). Between 25 and 50 m, 303 birds were expected rather than 521 ($X^2 = 155$, df = 2, $P < 0.001$). The 365 individuals recorded beyond 50 m was less than the expected 1,216 birds ($X^2 = 595$, df = 2, $P < 0.001$).

In west Tennessee bottomlands. distance to each bird was recorded in one of four concentric bands: <30 m, 30 to 60 m, 61 to 322 m, or >122 m. Generally, spatial distribution of bird counts was similar to the lower MAV with most of the individuals recorded in the intermediate distance categories (table 5). However, the percentage of total observations recorded in each distance category varied among years and between lo-minute and 20-minute point counts (table 5). Generally, more birds were detected beyond 122 m during 20-minute counts, especially in 1985 and 1986. In 1987, eight and five times more birds were recorded beyond 122 m during 10- and 20-minute point counts, respectively, than in previous years. Most of the corresponding decrease occurred between 30 and 60 m with only half the number of birds recorded in this category during 1987 as recorded in 1985 or 1986.

At least some of the annual variation in west Tennessee can be attributed to habitat variation, particularly the landscape context of point counts. Censuses in 1987 occurred in much smaller forest patches than those in 1985 or 1986. An important consideration in conducting point counts among sites that vary greatly with respect to total area, or core area (Temple 1986), is the number of edge-associated bird species that are within sampling distance. Corvids, icterids, and many other edge associates (e.g., northern cardinal [*Cardinalis cardinalis*]) typically have loud vocalizations and thus are more readily detected at greater distances than interior forest species. If the difference in point counts relative to landscape context increases the proportion of loud edge associates, then the percentage of birds detected in the farthest distance category should increase. A significant relative increase in number of species detected at greater distances would necessarily result in lower percentages in other categories. However, decreases were not proportional among remaining categories and the previous scenario does not adequately explain why a greater decrease occurred between 30 and 60 m (≥50 percent) as compared to <30 m (20 percent) or 61 to 122 m (30 percent).

There are several other factors that potentially influence the number of birds detected at varying distances. For all species, detection rates decrease with increasing distance from the observer (Jarvinen and Vaisanen 1975, Scott and Ralph 1981, Verner 1985). Moreover, detection distances and the effect of distance on detection differs among habitats and species (Jarvinen and Vaisanen 1975, Scott and Ralph 1981, Verner 1985). In the lower MAV study, a slightly greater number of birds in the dry habitat were detected at greater distances (table 4), perhaps because this habitat was more open. Also, an analysis of numbers detected for three species showed no consistent pattern, except that fewer birds were detected

Table 4.—*Number (N) and percentage of individual birds detected for each habitat within distance category in the lower Mississippi Alluvial Valley, 7 through 16 May 1992*

Distance category	Habitat					
	Wet		Mesic		Dry	
Meters	*N*	*Percentage*	*N*	*Percentage*	*N*	*Percentage*
<25	127	28.3	126	32.3	87	25.7
25 to 50	217	43.4	166	40.4	138	40.5
>50	130	28.3	110	27.3	125	33.8
Total	474	100.0	402	100.0	350	100.0

Table 5.-*Percentage of individual birds (for each year and overall) detected within each* distance *category during IO-minute and 20-minute point counts across seven major drainages in west Tennessee bottomlands*

Distance category	*1985*		1986		1987		1985-87	
	10*	20*	10*	20*	10*	20*	10*	20*
Meters	*Percent*							
<30	18.8	17.4	17.5	16.1	13.8	12.8	17.6	16.3
30-60	36.3	35.1	34.8	32.0	16.2	15.5	32.8	31.2
61-122	39.7	36.7	42.5	41.2	29.3	29.2	39.3	37.6
>122	5.2	10.8	5.2	10.7	40.7	42.5	10.3	14.9
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

*Length of point counts in minutes.

farther away. Of the three species examined, only the red-eyed vireo showed significant variation in detection relative to distance ($F = 7.29$; df = 2,31; $P = 0.003$). Only one red-eyed vireo was ever detected at a distance greater than 50 m, probably owing to the difficulty of hearing or distinguishing its song at great distances. Although the mean number of prothonotary warblers recorded appeared to decrease with increasing distance from the observer (1.81, 1.47, and 1.33 per count, respectively), detection of prothonotary warblers across distance categories was not significantly different ($F = 1.34$; df = 2,46; $P = 0.272$). Northern cardinals, which sing loudly, were detected in almost equal numbers at all three distances ($F = 0.700$; df = 2,64; $P = 0.505$).

Despite differences in detection rates among species and the many other variables that may influence detection probabilities (e.g., point count duration, habitat features, landscape context), the relative frequency of birds recorded among distance categories in west Tennessee and the lower MAV were similar in some important ways. In both studies, significantly more birds were recorded within 25 or 30 m than would be expected from the corresponding proportions of total area included within each of these concentric bands. But in neither study did the relative frequency of birds in the closest category represent an overwhelming percentage of the total. Rather, in both studies 35 to 40 percent of the total birds encountered were recorded in the second distance category (25 to 50 m or 30 to 60 m) except in west Tennessee in 1987. Moreover, when the same (or similar) sites were visited from one year to the next, the percentage of birds recorded in each distance category remained remarkably similar (table 5). For example, 5.2 percent of lo-minute counts were recorded beyond 122 m in 1985 and 1986; corresponding values for 20-minute counts were 10.8 percent and 10.7 percent. Preliminary data should probably be gathered for any specific set of circumstances, but these data suggest that the recommended distance measures for point count plots (Ralph and others, in press) are useful in bottomland hardwood forests of the lower MAV and associated drainages.

Variation Among Point Counts and Minimum Sample Size

There was significant variation in numbers of both individuals and species per count for the lower MAV (table 6). Mean number of individuals ranged from 10.8 birds per count in wet habitat within the central region to 20.0 birds per count in mesic habitat within the southern region. Corresponding values for species

Table 6.—*Means and standard deviation (S.D.) for individual birds and species per count among regions, localities, and habitats in the lower Mississippi Alluvial Valley, 7 through 16 May 1992*

				Individuals		Species	
Region	Locality	Habitat	n*	Mean	S.D.	Mean	S.D.
Southern	1	wet	4	13.5	2.89	8.3	1.26
	1	mesic	4	14.5	3.11	8.5	1.91
	2	wet	5	17.4	2.30	11.0	1.87
	2	mesic	1	20.0	0.00	11.0	0.00
	2	dry	3	18.0	1.73	10.0	1.73
	3	wet	5	19.6	4.28	11.2	2.17
	3	mesic	4	16.3	1.89	11.3	0.96
Central	1	mesic	4	12.5	4.51	9.3	2.75
	1	dry	5	16.0	2.12	12.0	1.87
	2	wet	2	14.5	4.95	9.0	0.00
	2	mesic	3	13.0	1.00	9.0	1.00
	2	dry	3	14.0	2.00	9.7	1.53
	3	wet	5	10.8	3.11	8.6	1.82
	3	mesic	2	12.0	4.24	8.5	3.54
	3	dry	4	13.0	2.45	9.5	1.29
Northern	1	wet	3	12.7	1.53	10.7	0.58
	1	mesic	3	16.7	1.53	11.3	0.58
	1	dry	3	15.3	2.08	11.0	1.00
	2	wet	3	19.0	0.00	13.7	2.08
	2	mesic	3	13.0	1.00	9.3	1.15
	2	dry	3	15.7	3.79	11.7	2.52
	3	wet	4	14.0	1.41	10.8	0.96
	3	mesic	4	14.5	3.32	11.5	2.89
	3	dry	2	14.5	0.71	10.0	0.00
Overall			82	15.0	0.37	10.3	0.22

*Number of point counts.

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, standard deviation [S.D.] = 3.07); the southern and northern regions averaged 16.8 (S.D. = 2.20) and 15.0 (S.D. = 2.16), respectively. The central region also averaged the fewest species per census (9.6, S.D. = 1.93). Mean number of species per census in the southern region was 10.2 (S.D. = 1.74), whereas the northern region averaged 11.2 (SD. = 1.70).

Variation Among Regions and Localities.-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 7). This result suggests that at the smaller 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 microrelief, 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. As suggested from our study, habitat distribution among regions varies considerably. (Recall that wet habitat appeared less abundant in the central region, whereas dry habitat was difficult to find in the southern region.)

Minimum Sample Size.-There are two major approaches to estimating minimum sample size. The "non-power method" (Ott 1977), calculates the mini-

Table 7.—*ANOVA tables (overall models) for the number of species and individual birds per count**

Effect	*df*	*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		

*Region and habitat were treated as main effects with patch nested within region.

mum sample size for a specified difference between two means, given the variance in the data, but only considers the probability of making a Type I statistical error (a; the probability of rejecting the null hypothesis if it is true). The "power method" (Neter and Wasserman 1974) calculates minimum sample size relative to the probability of making Type I and Type II errors. (The probability of making a Type II error is designated by β. It is the probability of accepting the null hypothesis if it is false; $1-\beta$ is called the "power" of the test. For more on the importance of considering power in statistical tests, see Forbes 1990.) 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 8); 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.

Regardless, 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. Minimum sample sizes were calculated for a variety of differences among means, and for several different variables: number of species, number of individuals, and for selected species exhibiting different distributions and abundances throughout the lower MAV (table 8). Furthermore, the appendix summarizes minimum sample sizes for 20 selected species (including the 8 most abundant species) with locality level differences among all 3 regions.

For each variable in table 8, four minimum sample sizes are presented. 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.[4] The numbers in the column for the "actual difference" are 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, 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 8) could only have been significant for the prothonotary warbler or the red-eyed vireo.

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 H.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 thrushes was 0.23 per census (table 8); a difference of ±0.25 individuals becomes an increase or decrease of >100 percent of the mean. This was the case for the majority of species in the lower MAV, including 9 of the 20 more common species (appendix).

Perhaps a better approach for estimating minimum sample sizes of individual species is to specify some relative change in population abundance. For this reason, a column was included in table 8 and the appendix that summarizes sample sizes for 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., $\mu_j - \mu$; Neter and Wasserman 1974, p. 493). Selecting an appropriate magnitude of relative change will depend on the objectives of the research or monitoring program. Sample sizes required to detect differences of ±25 percent of the mean were calculated because they should frequently reflect biologically meaningful changes and because they represent an achievable goal for most public and private land managers. For more detailed research endeavors such as modeling population dynamics or performing population viability analyses of threatened or endangered species, consistent detection of smaller relative changes may be necessary.

Finally, to provide a different perspective on the question of sample size, minimum difference detected among factor level means (given the MSE) with a

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[4] Note that the minimum sample sizes in table 8 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. The values in table 8 are a useful approximation.

Table 8.—*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 variations among factor levels in this study (unless otherwise noted a = 0.05 and β = 0.10)*

Variable	MSE*	Mean’	Range’	Actual difference!	±0.25 birds[¶]	±25% of mean**	Difference 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[‡‡]	1.144	1.71	1.04	28	>200	44	0.655
Habitat	1.326	1.59	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	0.858	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

*Mean square error of one-way analysis of variance, with three levels of treatment (for example, northern, central, and southern region).

‘Mean birds per count; this value is the same for region and habitat.

[‡] Range between the means for the highest and lowest levels of treatment.

[§] Sample size that is required to get statistical significance for the actual observed difference among factor level means (range).

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

**Sample size that would be required to detect a significant difference between two treatments, i.e., between 25 percent above and 25 percent below the overall mean. (The difference between two treatment means of 50 percent of the overall mean.)

[††] The difference (in number of birds) that could be significantly detected by a sample size of 70.

[‡‡] 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.

sample size of 70 are presented in table 8. A sample size of 70 initially was selected for this exercise because it was the largest sample size value presented in the table of curves (Neter and Wasserman 1974, p. 827). Since then, however, it was 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 to 60, especially for differences that probably are biologically significant. For species that have large differences relative to their overall mean (e.g., prothonotary warbler), minimum sample size could be much smaller, especially if the study were designed carefully with respect to selected variables and factor levels. For example, an analysis of region and habitat choices by prothonotary warblers at 3 factor levels would require 27 counts (9 counts per factor level). Conversely, species that have more variation and exhibit smaller differences (e.g., northern cardinal) would require larger sample sizes.

Despite the variation among species, however, 50 point counts per factor level should be sufficient to detect most of the biologically meaningful differences. Thus, a study comparing species distribution and abundance among 3 forest fragment 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 or 'more censuses) should be obtained from each of the 150 forest patches. In this example, using only three levels of fragment size categories (in contrast to five categories) would both reduce the total number of point counts needed and increase the number of habitat fragments available in each size category.

Finally, other means of reducing sample size are to accept a higher probability of rejecting the null hypothesis when it is true (i.e., accept an $a > 0.05$) or to 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 *a* 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.

Allocation of Sampling Effort

Points Versus Visits in Delta Experimental Forest.—All possible combinations of six visits to each of six points initially were compared 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. Each year was considered independently because total species recorded in DEF during 1991 (Species total [S] = 39) and during 1992 (S = 55) were substantially different, mostly because of late flooding. in 1991. Significant variation in mean cumulative species occurred among number of points and number of visits to each point both in 1991 ($F = 91.30$, df = 35, $P < 0.0001$) and 1992 ($F = 89.78$, df = 35, $P < 0.0001$) (table 9). There was no significant interaction between number of points and number of visits but 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 ($R^2 = 0.9668$) (table 9).

Table 9.—*Summary data from ANOVA analysis where mean cumulative number of species recorded during point counts of birds was modeled as a function of number of points and number of visits to each point during 1991 and 1992, Delta Experimental Forest, Stoneville, MS*

1991

Source	df	Sum of squares	Mean square	F value	$P > F$
Model	35	1482.01	42.34	91.30	0.0001
Error	108	50.09	0.46		
Corrected total	143	1532.10			
R^2* = 0.9673					

Source	df	Type III Sum of squares	Mean square	F value	$P > F$
Points	5	944.61	188.92	407.35	0.0001
Visits	5	535.49	107.10	230.92	0.0001
Points* visits	25	1.90	0.07	0.16	1.0000

1992

Source	df	Sum of squares	Mean square	F value	$P > F$
Model	35	3584.08	102.40	89.78	0.0001
Error	108	123.18	1.14		
Corrected total	143	3707.26			
R^2* = 0.9668					

Source	df	Type III Sum of squares	Mean square	F value	$P > F$
Points	5	2276.96	455.39	399.26	0.0001
Visits	5	1306.12	261.22	229.03	0.0001
Points* visits	25	1.00	0.04	0.04	1.0000

*The coefficient of determination.

In 1991, cumulative number of species increased significantly with each added point through five points (fig. 6), but six points did not differ from five points (F = 3.19, minimum significant difference = 0.7853, df = 108, $P < 0.01$). Similarly, cumulative number of species increased with each revisit up to four visits, but four visits did not differ from five visits (F = 3.19, minimum significant difference = 0.7853, df = 108, $P < 0.01$). Total increase in cumulative number of species with counts conducted at 6 points (across all 6 visits) averaged 7.4 and represented an addition of 20 percent of the species pool to our estimate (table 10). Total increase in cumulative number of species with six visits (across all 6 point&/averaged 5.49, 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

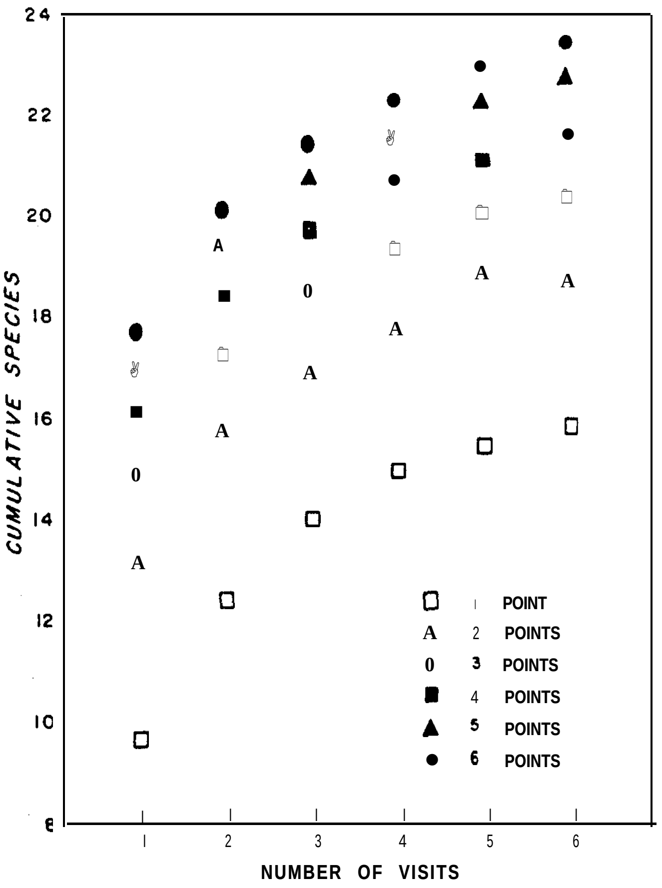

Figure 6.—*Cumulative number of* bird *species recorded during 1991 censuses for all possible combinations of six visits to each of six points on Delta Experimental Forest, Stoneville, MS.*

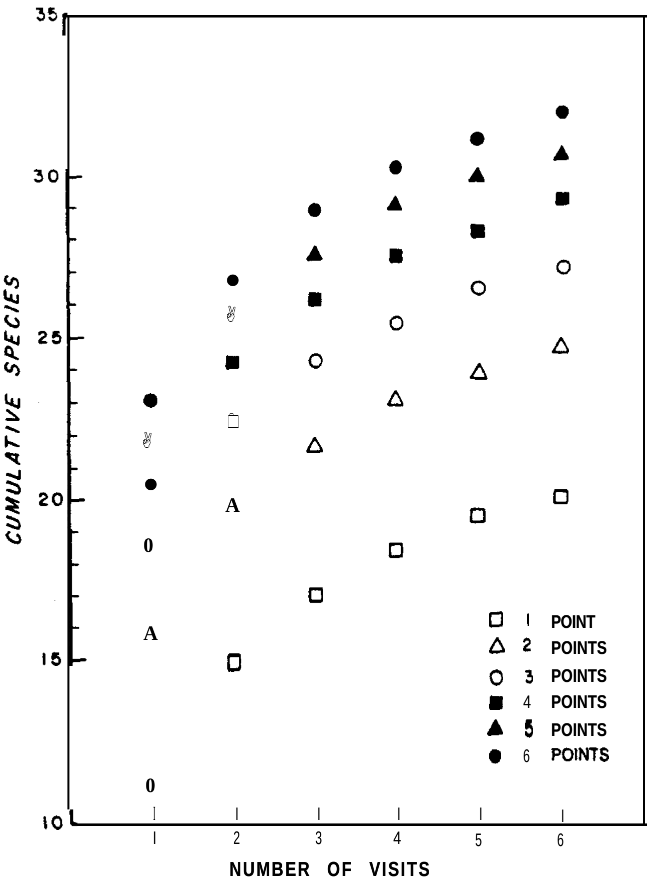

Figure 7.—*Cumulative number of bird species recorded during 1992 censuses for all possible combinations of six visits to each of six points on Delta Experimental Forest Stoneville,* MS.

points, whereas significant increases with revisits occurred through four visits as in 1991 (*F* = 3.19, minimum significant difference = 1.2316, df = 108, *P* <0.01) (fig. 7). Average total increase in cumulative number of species with 6 points in 1992 was 11.82, representing a 21 percent increase in our species estimate; 6 visits increased the total cumulative number of species by 8.9, a 16 percent increase in total number of species (table 10).

Although no interaction was detected between points and visits,, when all possible paired reciprocals (e.g., 1 point and 2 visits vs. 2 points and 1 visit) were compared, 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. 8) and 1992 (fig. 9). 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. 8) and 1992 (fig. 9).

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. 10). Increasing revisits beyond five visits in 1991 did not improve our ability to capture more of the species pool (fig. 11); in 1992 a sixth visit increased the efficiency by 1.4 percent ($\blacktriangle p_i$ = 0.014). In both years, increased efficiency ($\blacktriangle p_i$) began to decrease rapidly beyond three visits and three points.

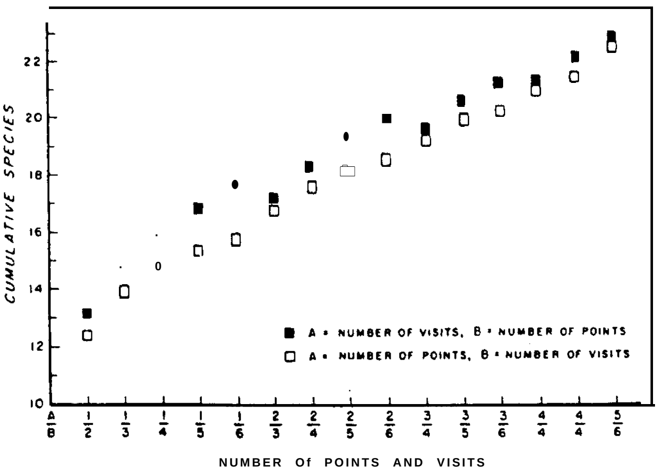

Figure *R-Comparison of cumulative number of bird species recorded between 15 possible paired reciprocals (i.e., 1 point-2 visits vs. 2 points-l visit) of number of points visited and number of visits to each point, Delta Experimental Forest, Stoneuille, MS, 1991.*

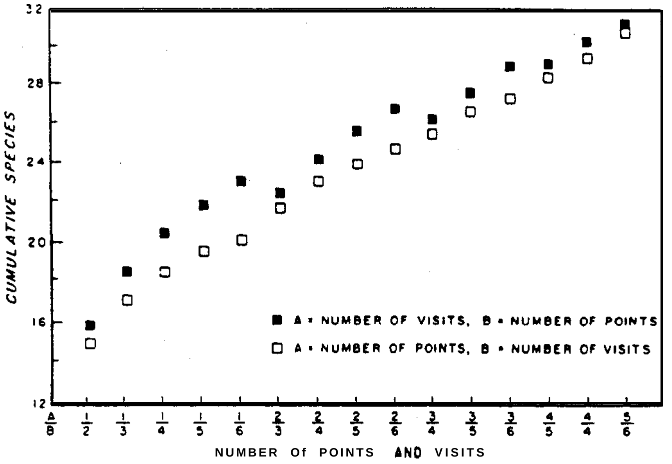

Figure *9.-Comparison of cumulative number of bird species recorded between 15 possible paired reciprocals (i.e., 1 point-2 visits vs. 2 points-l visit) of number of points visited and number of visits to each point, Delta Experimental Forest, Stoneville, MS, 1992.*

Table 10.—*Mean cumulative number of species obtained from bootstrap estimates of all possible combinations of six points and six visits to each point during 1991 and 1992 bird censuses, Delta Experimental Forest, Stoneuille, MS*

	Visits					
Points	1	2	3	4	5	6
	Mean cumulative number of species					
1991						
1	9.66	12.37	13.97	14.92	15.43	15.83
2	13.15	15.76	16.88	17.69	18.23	18.65
3	14.92	17.25	18.49	19.34	20.06	20.36
4	16.12	18.39	19.70	20.66	21.06	21.54
5	16.94	19.37	20.70	21.43	22.20	22.67
6	17.69	20.10	21.40	22.26	22.95	22.39
1992						
1	11.16	14.92	17.12	18.52	19.55	20.14
2	15.85	19.81	21.72	23.12	23.99	24.75
3	18.56	22.49	24.31	25.49	26.61	27.30
4	20.47	24.21	26.20	27.50	28.37	29.36
5	21.86	25.64	27.56	29.09	30.03	30.74
6	23.05	26.75	28.96	30.26	31.22	32.07

***Points** Versus Visits Versus Duration in West Tennessee.*-Point counts from west Tennessee bottomlands provided an opportunity to examine simultaneously the three important variables in a single study. We used ANOVA to model mean cumulative number of species as a function of number of points, number of visits to each point, and duration of point counts. The comparison was conducted by selecting combinations of numbers of points, visits, and durations for which the total length of observation time was 20 minutes, the duration of the longest individual counts made in west Tennessee. Four combinations were subjected to the test: four 5-minute counts at a single point, two lo-minute counts at a single point, single lo-minute counts at two separate points, and a single 20-minute count. In the analysis, the combination of two 5-minute counts at two separate points was not calculated. Limits of the original data prevented calculation of another desirable combination for the analysis, single B-minute counts at four

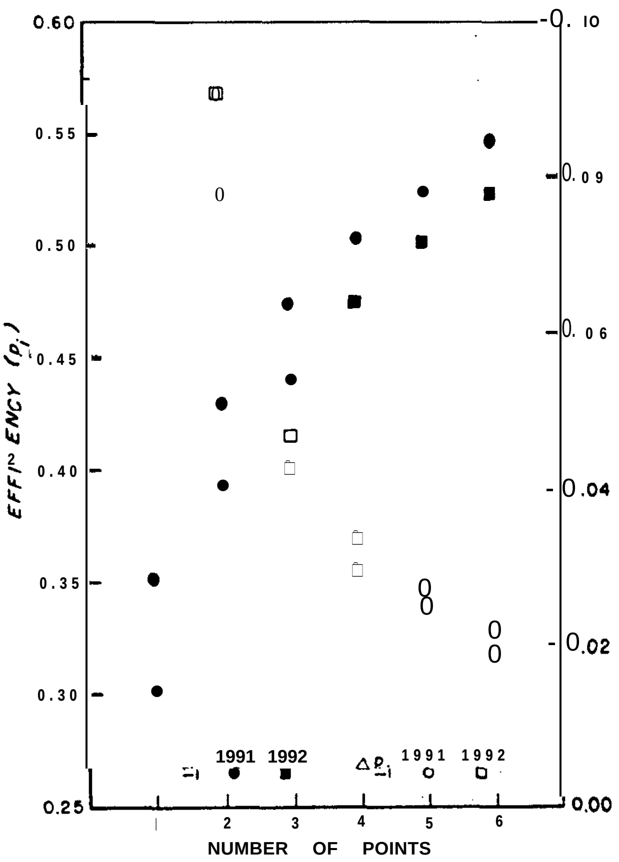

Figure 10.--*Proportion of 1991 and 1992 species pool included in point count censuses (EFFICIENCY, p_i) and change in efficiency (Δp_i) relative to number of points visited at a locality, i.e., forest stand (averaged across all six visits), Delta Experimental Forest, Stoneville, MS.*

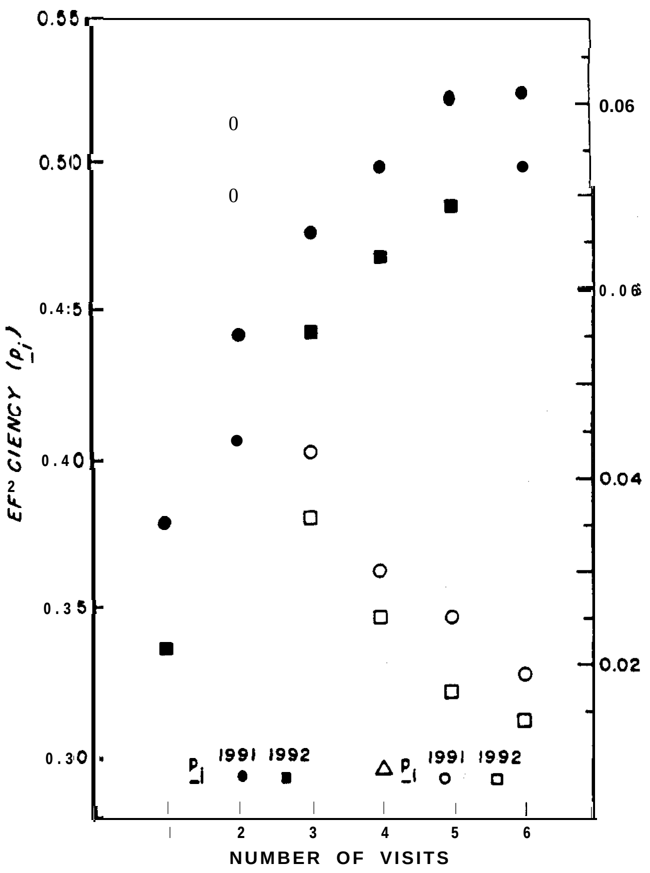

Figure 11.-*Proportion of 1991 and 1992 species pool included in point count censuses (EFFICIENCY, p_i) and change in efficiency (Δp_i) relative to number of visits to each point at a locality, i.e., forest stand (averaged across all six points), Delta Experimental Forest, Stoneville, MS.*

points. The resulting ANOVA model was significant ($F = 21.80$; df = 2,137; $P < 0.0001$), explaining about 24 percent of the variation ($R^2 = 0.24$) in mean cumulative number of species (table 11). Simultaneous comparisons of the mean cumulative number of species indicated that four counts of 5-minute duration yielded 2.8 more species than either combination of two 10-minute counts, and the latter yielded 2.2 more species on average than a single 20-minute count (table 12). Comparisons of number of points and number of visits of constant duration supported conclusions from the lower MAV that more points yielded greater cumulative number of species than more visits.

CONCLUSIONS AND RECOMMENDATIONS

Considerable variation in number of individual birds and number of species was observed among localities, habitats, regions, and even between years at the same site; yet, the general response functions of number of individuals or number of species recorded per unit time during point counts in bottomland hardwood forests appear to be comparable among years and across geographic regions. Point counts should be at least 5 minutes in duration, an initial 3-minute count plus an additional 2 minutes. Point counts longer than 10 minutes are not justified because of a reduction in efficiency, unless logistics preclude additional points during a morning sampling period. Excluding logistic considerations, visiting more points is always better than an equivalent number of visits to the same point or extending the duration of a point count by an equivalent amount of time. Because of the horizontal and vertical density of vegetation in bottomland hardwoods, birds should be recorded in three concentric bands: <25 m, 25 to 50 m, and >50 m. Given the variability and range of factor levels considered in this study, a sample size of 50 point counts per factor level should be sufficient to detect most of the meaningful differences in bottomland hardwood forests of the lower Mississippi Alluvial Valley and associated drainages. These recommendations are compatible with the protocol recommended by the Monitoring Working Group.

Table 11.—Summary *data from ANOVA analysis where mean cumulative number of species recorded during point counts of birds was modeled as a function of total duration of counts for counts of cumulative duration of 20 minutes of observing, during the breeding season, 1985–87, in west Tennessee bottomlands*

Source	df	Sum of squares	Mean square	F value	$P > F$
Model	2	297.63	148.82	21.80	0.0001
Error	137	935.13	6.83		
Corrected total	139	1232.76			
$R^2 = 0.2414$					

Source	df	Type IV Sum of squares	Mean square	F value	$P > F$
Duration	2	297.63	148.82	21.80	0.0001

Table 12.—*Mean cumulative number of species from point counts of birds in west Tennessee bottomlands, 1985-87, for censuses representing varying numbers ofpoints, numbers of visits to each point, and total duration of sampling effort (time) in minutes for counts of cumulative duration of 20 minutes*

Combination	Sample size	Mean number species*	S.D.	Minimum	Maximum
1 20-min visit to a single point	57	18.82	2.28	12.48	22.68
2 10-min visits to a single point	55	20.89	2.86	14.10	26.32
1 10-min visit to each of 2 points	18	21.62	2.75	16.06	25.00
4 5-min visits to a single point	10	23.91	2.73	19.16	27.96

*Each observation represents the result of 50 simulation runs by bootstrapping from the original data points of that combination of points, visits, and duration.

LITERATURE CITED

American Ornithologists' Union. 1983. Check-list of North American birds. 6th ed. Lawrence, KS: Allen Press, Inc. 877 p.

Anderson, Bertin W.; Ohmart, Robert D. 1981. Comparison of avian census results using variable distance transect and variable circular plot techniques. Studies in Avian Biology. 6: 186-192.

Blondel, J.; Ferry, C.; Frochot, B. 1970. La méthode des indices ponctuels d'abondance (IPA) ou des relevés d'avifaunepar "stations d'écoute." Alauda. 35: 55-71.

Burdick, David M.; Cushman, Douglas; Hamilton, Robert; Gosselink, James G. 1989. Faunal changes and bottomland hardwood forest loss in the Tensas watershed, Louisiana. Conservation Biology. 3: 282-292.

Delta Council. 1945. Delta bottomland hardwoods. Stoneville, MS: Delta Council. 23 p.

Durham, Daryl B.; Abernethy, Robert K.; Eagar, Daniel C. [and others]. 1988. Application of the Habitat Evaluation System to modeling bottomland hardwood forest communities in west Tennessee. Transactions of the North American Wildlife and Natural Resources Conference. 53: 481-490.

Efron, Bradley. 1982 The jackknife, the bootstrap, and other resampling plans. Monogr. 38. Philadelphia, PA: Society for Industrial and Applied Mathematics, Conference Board of the Mathematical Sciences-National Science Foundation regional conference series in applied mathematics. 92 p.

Forbes, L. Scott. 1990. A note on statistical power. Auk. 107: 438-439.

Ford, Robert P. 1990. Habitat relationships of breeding birds and winter birds in forested wetlands of west Tennessee. Knoxville, TN: University of Tennessee. 129 p. M.S. thesis.

Hurlbert, Stuart H. 1984. Pseudoreplication and the design of field experiments. Ecological Monographs. 54(2): 187–211.

Jarvinen, Olli; Vaisanen, Risto A. 1975. Estimating relative densities of breeding birds by the line transect method. Oikos. 26: 316-322.

Neter, John; Wasserman, William. 1974. Applied linear statistical models. Homewood, IL: Richard D. Irwin, Inc. (p. 493, 549, 827). 842 p.

Ott, Lyman. 1977. An introduction to statistical methods and data analysis. North Scituate, MA: Duxbury Press. 730 p.

Ralph, C. John; Geupel, Geoffrey R.; Pyle, Peter [and others]. [In press]. Field methods for monitoring landbirds. Gen. Tech. Rep. San Francisco: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station.

SAS Institute, Inc. 1988. SAS/STAT User's Guide. Release 6.03 ed. Cary, NC: SAS Institute, Inc. (p. 560). 1,028 p.

Scott, J. Michael; Ralph, C. John, eds. 1981. Estimating numbers of terrestrial birds. Studies in Avian Biology. 6: 1-630.

Scott, J. Michael; Ramsey, Fred L. 1981. Length of count period as a possible source of bias in estimating bird densities. Studies in Avian Biology. 6: 409-413.

Temple, Stanley A. 1986. Predicting impacts of habitat fragmentation on forest birds: a comparison of two models. In: Verner, Jared; Morrison, Michael L.; Ralph, C. John, eds. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Madison, WI: University of Wisconsin Press: 301-304.

U.S. Department of the Interior. 1990. Breeding bird survey: instructions for conducting the breeding bird survey. Laurel, MD: U.S. Department of the Interior, Fish and Wildlife Service. 4 p.

Verner, Jared. 1985. Assessment of counting techniques. In: Johnston, Richard F., ed. Current ornithology. New York: Plenum: 247-302. Vol. 2.

Zar, Jerrold H. 1984. Biostatistical analysis. 2d. ed. Englewood Cliffs, NJ: Prentice-Hall, Inc. 718 p.

Appendix

Minimum sample sizes for selected species recorded during point counts in the lower Mississippi Alluvial Valley. Sample size was calculated according to the power method (for α = 0.05 and β = 0.10) with several detectable difference values among factor level means

Species	MSE*	Mean*	Actual difference*	±0.25 birds	±25 percent of mean
Acadian flycatcher+					
Region	0.59	0.915	53	65	80
Locality					
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
Locality					
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
Locality					
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
Locality					
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
Locality					
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
Locality					
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
Locality					
Southern	0.15	0.192	33	15	>200
Central	0.00	0.000	z-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
Locality					
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

*Minimum sample sizes **for** selected species recorded during point counts in the lower Mississippi Alluvial Valley. Sample size was calculated according to the power method **(for** α = 0.05 and β = 0.10) with several detectable difference values among factor level means-Continued*

Species	MSE*	Mean*	Actual difference*	zt0.25 birds	±25 percent of mean
Kentucky warbler					
Region	0.09	0.110	80	9	>200
Locality					
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
Locality					
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
Locality					
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
Locality					
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
Locality					
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
Locality					
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
Locality					
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

Minimum sample sizes for selected species recorded during point counts in the lower Mississippi Alluvial Valley. Sample size was calculated according to the power method (for a = 0.05 and β = 0.10) with several detectable difference values among factor level means-Continued

Species	MSE*	Mean*	Actual difference*	±0.25 birds	±25 percent of mean
Tufted titmouse’					
Region	0.52	0.878	58	53	80
Locality					
Southern	0.47	0.615	15	50	>200
Central	0.44	0.893	15	44	56
Northern	0.45	1.107	33	44	37
Habitat	0.56	0.876	>200	58	85
Wood thrush					
Region	0.23	0.232	>200	27	>200
Locality					
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
Locality					
Southern	0.45	0.885	>200	44	65
Central	0.36	0.607	27	37	100
Northern	0.42	0.590	23	44	>200
Habitat	0.45	0.659	>200	44	>200
Yellow-throated vireo					
Region	0.05	0.049	100	9	>200
Locality					
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

*Calculated from the observed variation among factor levels.

‘The most abundant species, i.e., those whose totals comprised >50 percent (8720,621) of all birds recorded during point counts conducted throughout the lower Mississippi Alluvial Valley, 7 through 16 May 1992.

Smith, Winston Paul; Twedt, Daniel J.; Wiedenfeld, Paul B. [and others]. 1993. Point counts of birds in bottomland hardwood forests of the Mississippi Alluvial Valley: duration, minimum sample size, and points versus visits. Res. Pap. SO-274. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station. 21 p.

To compare efficacy of point count sampling in bottomland hardwood forests, duration of point count, number of point counts, number of visits to each point during a breeding season, and minimum sample size are examined.

Keywords: Census, neotropical migrant birds, power method, sampling protocol.

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