Analysis of Sample Size, Counting Time, and Plot Size from an Avian Point Count Survey on Hoosier National Forest, Indiana[1]

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Abstract: We report results of a point count survey of breeding birds on Hoosier National Forest in Indiana. We determined sample size requirements to detect differences in means and the effects of count duration and plot size on individual detection rates. Sample size requirements ranged from 100 to >1000 points with Type I and II error rates of <0.1 and 0.2. Sample size was inversely related to species abundance ($r = -0.38$, $P < 0.01$). Counting efficiency was maximized at a count duration <6 minutes with a travel time of 8 minutes, but differences were slight for most travel times. Unlimited-radius plots detected more individuals than 50-m or 70-m radius plots ($P < 0.05$). We recommend serious consideration of Type II error when designing monitoring protocols. Secondary study objectives and the need for standardization should be weighed heavily when selecting counting time in the range of 5 to 10 minutes. We recommend the use of unlimited-radius plots while simultaneously recording individuals relative to a fixed radius.

Populations of some forest-dwelling Neotropical migrant birds appear to be declining in Northeastern America (Askins and others 1990, Robbins and others 1989, Wilcove and Robinson 1990). Information is needed for the development of standardized monitoring protocols that will allow determination of local population trends of migrant landbirds as well as regional comparisons of population trends. Point counts are a potentially efficient and cost effective method of monitoring population trends and habitat associations. Our objectives in this paper are to determine the effects of bird abundance and variability on the sample size required to detect a difference in mean abundances, determine the effects of count duration on counting efficiency, and to compare detection rates on fixed- and unlimited-radius plots.

Study Area

Point counts were conducted on the Hoosier National Forest, which is composed of approximately 80,939 ha of noncontiguous ownership in southern Indiana. The landscape includes the National Forest and intermixed lands in other ownerships, and is a patchwork of forest and openlands fragmented by roads, farms, industrial developments, towns, small cities, and utility corridors. The area ranges from 5 percent to 80 percent forest cover. The diversity of the landscape results in a variety of habitats that range from mesophytic communities in deep ravines and lower slopes to xerophytic communities on limestone knobs and ledges, and sandstone ridge crests. Natural forest communities are primarily oak (*Quercus* spp.) dominated types. Other associations include hemlock (*Tsuga* sp.), beech (*Fagus* sp.)-oak-maple (*Acer* sp.), mixed mesophytic, swamp forests, and mixed floodplain forests.

Methods

Counting Methods

We located a total of 300 points in 12 study sites 4 km in diameter. Four study sites were located in each of three forest units that roughly correspond to the three dominant natural divisions of Indiana that fall within the Hoosier National Forest. In addition to stratifying by natural division, in each unit two sites were located in contiguous forest and two in forested areas fragmented by nonforest habitats. We permanently marked 25 points in each study site. We determined point locations by randomly laying a 250-m grid over a study site on a topographic map and selecting the 25 most centrally located points that were on the National Forest, in mature forest cover, and had no forest openings within 70 m. This sampling strategy may not be unbiased for monitoring population trends but we used it so we could relate bird abundances to landscape patterns as part of another study.

We counted birds during three 10-minute visits to each point between 0530 and 1000 hours, May 20 to June 20, 1991. Each of the three visits to a plot was by a different observer, so observer variability would be averaged over several observers (Verner 1987). We recorded all birds heard or seen and mapped their location on a data sheet relative to the center point, a 50-m radius, and a 70-m radius. We used superscripts after the first 6 minutes to indicate what minute of the count a bird was observed. The six different observers were either knowledgeable birders or recent ornithology students. To ensure competency in bird identification, observers received a training tape with songs or calls of 35 focal species and spent several days in the field with knowledgeable birders before monitoring. Focal species were common forest birds and predominantly Neotropical migrants or management indicator species for Hoosier National Forest.

Data Analysis

We included all bird detections (visual and aural, male and female) of focal species in the analyses. All calculations are based on the mean counts from the three visits to each of the 300 points. We calculated the mean and variance of the number of detections of each species from all points ($n = 300$). We estimated the sample size required to detect a 20 percent decline in abundance (one-way test) and difference in abundance (two-way test) at different probabilities of Type I and II error. Within the context of a monitoring study, Type I error is the probability of concluding that there is a decline or difference when in fact there is not, and Type II error is the probability of

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concluding that there is no difference or decline when in fact there is. We selected Type I error rates (α) of 0.05 and 0.10 and Type II error rates (β) of 0.10 and 0.20. Sample sizes were calculated from formulas for the difference in two means with equal variances and sample size (Snedecor and Cochran 1978:113). We calculated the Pearson correlation coefficient between estimated required sample size and species abundance (mean detections per point).

We calculated the mean number of species detected and the total individuals detected during 6-, 7-, 8-, 9-, and 10-minute counts to determine the most efficient count length. We used paired t.-tests to determine if the difference between 6- and 7-, 7- and 8-, 8- and 9-, and 9- and 10-minute counts were significant. The mean number of birds detected per hour of surveying was calculated from mean detection rates for 6- to 10-minute counts and travel times (noncounting time) of 6, 8, 10, 12, and 14 minutes. The mean number of detections per hour was equal to: D_t $(60/CT + TT))$, where D_t is the mean number of bird detections in a count t minutes long, CT is counting time in minutes, and TT is the travel time between points in minutes. We used bird detections per hour to evaluate count times because it incorporates both count time and travel time. Maximizing the number of individuals observed per hour (or morning) may maximize the probability of detecting species, result in the best estimates of relative abundance, and increase statistical power.

We compared the mean number of detections among counts on 50-m, 70-m, and unlimited-radius plots. We used paired t-tests to determine if the difference in the number of species detected within 50 m versus 70 m of a point, and 70 m versus an unlimited distance from a point, was significant. Because of the dependence in counts based on different radii from a common point, the significances of the *t*-tests may be liberal.

Results

We ranked the 21 most abundant species (species with >0.1 detections per point) by decreasing abundance (*table 1*). Estimated sample size requirements ranged from 101 for the most common species to over 2,000 for uncommon species (*table 1*). Sample size requirements for Type I and II error rates of ≤0.05 and 0.10 were approximately 90 percent higher than those for Type I and II error rates of ≤0.10 and 0.20. Sample size requirements for two-way tests were 22 percent higher than those presented in *table 1* for one-way tests. The estimated sample size required to detect a decline in the mean number of detections per point for each species was inversely related to a species mean abundance ($r = -0.38$, $P = 0.02$, $n = 36$).

Increases in the number of species detected and the total number of individuals detected were significant for each additional minute of counting time ($P \leq 0.01$) (*fig. 1*). Bird detections per hour of survey were greatest for counting times

Table 1--***Breeding bird abundance (mean detections per point) on Hoosier National Forest, Indiana, 1991, and the estimated sample size required to detect a 20 percent difference between two means (one-way test) when controlling for different levels of Type I and II error.***

			Required sample size	
Species	Mean $n = 300$	Standard Deviation	I[1] ≤0.10 II[2] ≤0.20	I ≤0.05 II ≤0.10
Red-eyed Vireo	1.49	1.438	208	398
Acadian Flycatcher	1.03	0.846	150	287
Scarlet Tanager	0.93	0.742	142	272
Ovenbird	0.92	0.771	155	297
American Crow	0.72	0.656	181	347
Tufted Titmouse	0.69	0.465	101	194
Wood Thrush	0.64	0.630	216	414
Eastern Wood-Pewee	0.63	0.611	210	401
Brown-headed Cowbird	0.53	0.557	244	467
Worm-eating Warbler	0.48	0.547	286	547
Pileated Woodpecker	0.40	0.372	189	362
Yellow-billed Cuckoo	0.37	0.372	219	419
Red-bellied Woodpecker	0.36	0.398	261	498
Indigo Bunting	0.33	0.445	400	764
Carolina Wren	0.25	0.380	520	994
White-breasted Nuthatch	0.21	0.298	437	835
Kentucky Warbler	0.16	0.319	817	1561
Great Crested Flycatcher	0.15	0.256	583	1114
Hooded Warbler	0.15	0.302	866	1655
Rufous-sided Towhee	0.14	0.322	1081	2066
Downy Woodpecker	0.12	0.205	632	1208

[1] Type I error.

[2] Type II error.

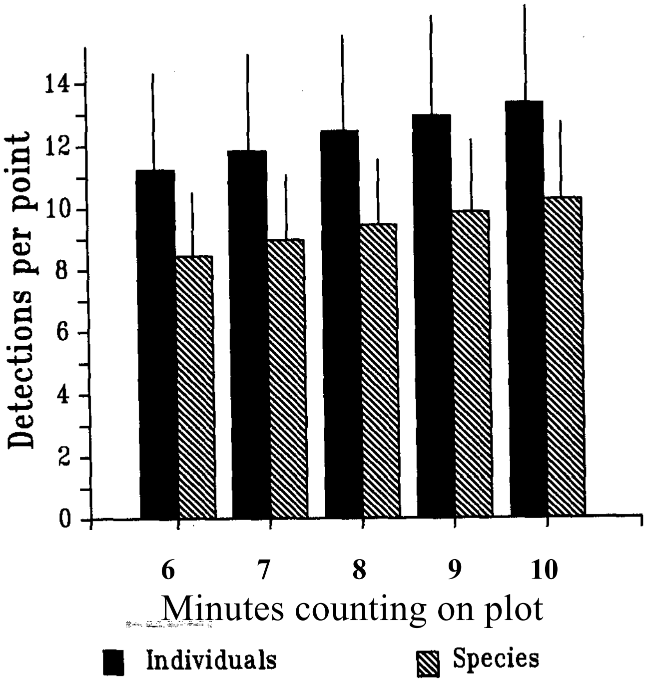

Figure 1--Mean (± 1 s.d.) number of individuals and species detected during 6- to 10-minute point counts of breeding birds on Hoosier National Forest, Indiana, 1991.

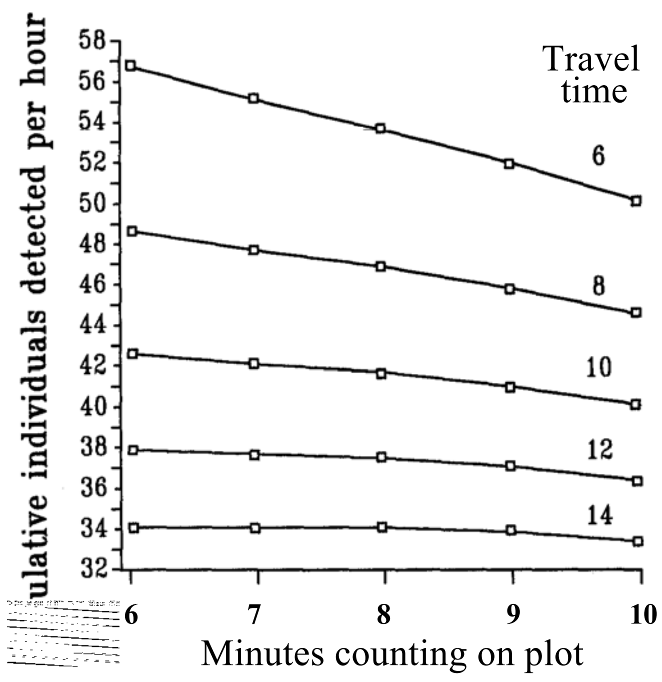

Figure 2--Estimated numbers of individual breeding birds detected per hour of survey for counting periods of different lengths and travel times on Hoosier National Forest, Indiana, 1991.

≤6 minutes when travel time was short, but counting times 6 to 8 minutes were most efficient for longer travel times (*fig. 2*). Actual travel time ranged from 5 to 30 minutes ($\bar{x} = 7.7$, *s.d.* = 5.04).

More individual birds were detected on 70-m radius plots than on 50-m radius plots, and on unlimited-radius plots than on 70-m radius plots ($P \leq 0.01$) (*fig. 3*).

Discussion

Based on the mean and variance of species detections per plot, our monitoring system appears adequate for detecting declines in the 13 most abundant species studied. We determined sample sizes required to detect a difference between two means. Monitoring programs that are interested in identifying long-term trends through regression or correlation analysis may not require as many points. Sample size requirements and power estimates were similar to those reported by Verner and Kie (1988) for a similarly designed monitoring system in California. Two alternative approaches that address sample size concerns for less common species are to monitor management guilds instead of single species (Verner 1984) or to pick monitoring sites that have a high probability of detection for focal species (Verner 1983, 1986). Both these approaches should result in higher detection rates, less variability, and more statistical power or smaller required sample sizes.

Sample size estimates required consideration of Type I and II error and the magnitude of difference we wanted to detect. Type I error is the probability of concluding that there is a decline or difference when in fact there is not, and Type II error is the probability of concluding that there is no difference or decline when in fact there is. Even with liberal levels of Type I and II error (0.1 and 0.2), a large number of points were required to detect a 20 percent difference among means. We recommend that monitoring efforts pay particular attention to Type II errors because they may have more important consequences to the conservation of a species than Type I errors. We suggest considering Type I error rates as high as 0.1 to increase statistical power to ≥0.8 or lower the probability of Type II error to ≤0.2.

The objectives of a monitoring system also greatly affect statistical power. A monitoring project with an objective to detect species declines (a one-way test) will require fewer samples or have more power than a study with the objective to detect changes or differences in abundance (a two-way test). Sample size requirements increased 22 percent for a two-way test over those presented for a one-way test (*table 1*).

In addition to monitoring population trends, a second objective of a monitoring study may be to compare relative abundance in habitats or regions. Our sample size estimates suggest that large numbers of points could be required to detect these differences. However, habitat-specific studies will likely sample finer classifications of habitats and, hence, have lower variances and sample size requirements than those in *table 1*.

A counting time of ≤6 minutes resulted in the greatest number of individuals detected per hour for our average travel time, but differences were slight for 6- to 10-minute counts with travel times ≥8 minutes. Because differences were slight, we believe the most important factor affecting counting time should be regional standardization to ensure that results of different studies are comparable. Alternative study objectives might warrant longer travel times. Maximizing the

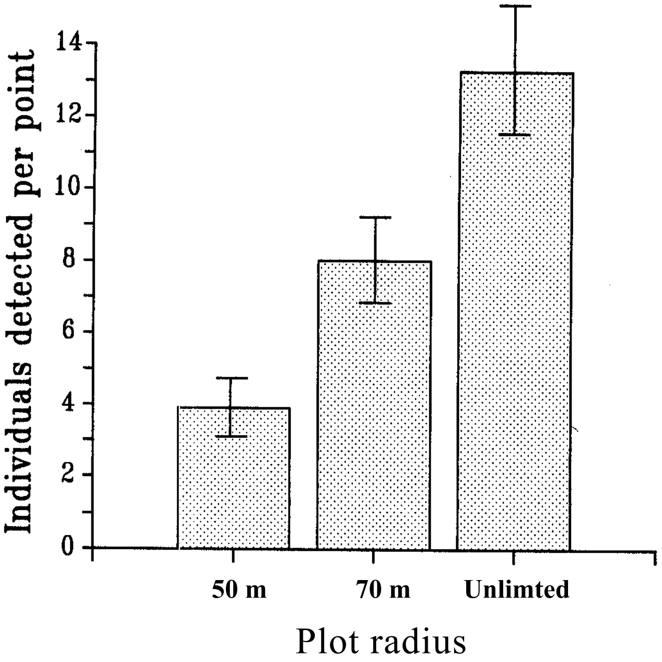

Figure 3--Mean (± 1 s.d.) number of individuals detected on plots of different radii during 10-minute point counts of breeding birds on Hoosier National Forest, Indiana, 1991.

number of individuals detected per hour of survey is appropriate when trying to minimize the number of points needed to detect population declines. Studies relating habitat or other characteristics of points to measures of bird abundance, however, should attempt to maximize the probability of detecting an individual because of the implications of failing to detect a species in a habitat when it is actually present. Under these circumstances longer counting times might be considered.

Unlimited-radius plots resulted in the highest detection rates and, therefore, probably will have the greatest statistical power. Counts on unlimited-radius plots could be affected by observer variability in hearing, but problems with distance estimation may cause comparable observer variability in fixed-radius plots. We recommend the use of unlimited-radius plots because they will result in more detections per plot and increased statistical power compared to 50- or 70-m radius plots. However, simultaneous recording of bird observations relative to a fixed radii also will allow analyses requiring a fixed size plot. Unlimited-radius plots may be undesirable when relating point characteristics to bird abundances because bird observations are not limited to a defined area that can be measured easily.

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