Design Recommendations for Point Counts of Birds in California Oak-Pine Woodlands: Power, Sample Size, and Count Stations Versus Visits[1]

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Abstract: *We used point count data from a 3-year experiment measuring the impact of firewood cutting on an oak woodland bird community to recommend a sampling design for detecting environmental impacts on bird population trends. The optimal allocation of sampling effort to count stations and visits varied from two to seven visits per station depending on the bird species. When the number of count stations was constrained by logistics, additional visits increased statistical power to detect an effect to acceptable levels (>0.5) for some species. Depending on the species, 14 to 920 count stations per treatment level were necessary to detect a 50 percent difference in the mean number of birds counted with power = 0.8.*

As California's oak (*Quercus* spp.) woodlands come under increasing pressure from human activities, so increases the need for the reliable detection of impacts on wildlife. In an experimental framework, the challenge is to isolate the effects of interest from natural spatial and temporal variability using an appropriate statistical test (Osenberg and others 1994). The power of a statistical test is the probability that it will find an effect of a specified size to be significant (Cohen 1988). Thus, power is critical in studies evaluating the impacts of environmental disturbances. These studies must be designed with adequate statistical power to detect biologically important changes in the population parameters of interest (e.g., density or reproductive success of a species). A possible result of failing to detect such changes may be the adoption or continuation of detrimental management practices, and perhaps extinction for some species.

In designing experiments, sample size is often seen as the primary means to control power. Certainly, sample size must be adequate to meet minimum power requirements, but in practice it is always subject to constraints. A fixed budget is a universal constraint on sample size, but logistical constraints, such as a small study area or limited potential for experimental treatments, may also exist.

Often overlooked is that, given a fixed budget, the statistical power of a study can be optimized by design. That is, different study designs of equal cost will have different power, and the researcher should select the optimal design. Such optimization requires information on the variance components of the population under study. The information may come from pilot studies or from previous experiments using similar populations. Thus, evaluating the efficiency of completed studies is a necessary first step toward maximizing the efficiency of future ones.

In woodland vegetation types, point counts have become a standard method for monitoring population trends in landbirds (Ralph and others 1993). Point counts are conducted by recording the number of individuals of target species detected from a counting station within a specified time interval. Frequently, stations are visited several times during a season to obtain an average index of population size. Although many studies have used point counts to detect the effect of environmental impacts on bird densities (deCalesta 1994, Wilson and others 1995), few have evaluated design efficiency once variance components are

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known. At least two studies have investigated the optimum allocation of sampling effort between count stations and visits (Buskirk and McDonald 1995, Smith and others 1995). However, because these optima are likely to be specific to particular vegetation types and bird species, further studies are needed to evaluate design efficiency in a variety of areas and vegetation types.

Here, we use point count data from a 3-year experimental study of the impact of firewood cutting on an oak woodland bird community in California to make specific recommendations about sample sizes necessary to meet power requirements and how to optimize the allocation of sampling effort to count stations and visits. Specifically, we address the following questions: (1) Assuming a fixed budget, what number of count stations and visits maximizes power to detect a specified difference between two group means (treatment and control)? (2) Assuming that the number of count stations is limited by logistical constraints, how does power increase with added visits? (3) Under the optimal allocation in (1), what sample sizes are necessary to detect biologically meaningful effects with reasonable power?

Study Area

We conducted field work at the University of California, Sierra Foothill Research and Extension Center, Yuba County, California, in the foothills of the northern Sierra Nevada mountains about 25 km east of Marysville. Elevation on the 2,300-ha Center ranged from 75 to 625 m with a general west to northwest aspect. Dominant trees were blue oak (*Quercus douglasii*), interior live oak (*Q. wislizenii*), and foothill pine (*Pinus sabiniana*), with fewer black oak (*Q. kelloggii*), valley oak (*Q. lobata*), ponderosa pine (*P. ponderosa*), and California buckeye (*Aesculus californicus*). Most stands contained mixtures of the three dominant species, although some pure stands of blue oak or live oak were present. Dominant shrubs were poison oak (*Toxicodendron diversilobum*), coffeeberry (*Rhamnus californica*), toyon (*Heteromeles arbutifolia*), and buckbrush (*Ceanothus cuneatus*). An herbaceous understory consisted of annual and perennial grasses and forbs.

Methods

Experimental Design and Field Methods

We used a completely randomized experimental design (Neter and others 1990:36-37) with a treatment and control replicated 30 times. The treatment consisted of a reduction of approximately 20 to 25 percent of total tree basal area, achieved by uniformly thinning commercial-grade (minimum 15-cm base diameter) blue oak and live oak. This level of thinning was chosen to represent a light firewood harvest. Experimental units were approximately 3.1-ha, circular plots centered on a single bird counting station. In a previous study, Block (1989) established 105 counting stations at 300-m intervals along linear transects (900 to 4,200 m) using a systematic random-sampling design (Thompson 1992). Of these, we selected 60 that were suitable for cutting for use in this experiment. Suitable plots were contained entirely on Center property, did not overlap with other researchers' plots, occurred mostly on slopes of less than 30 percent, and were accessible by vehicle. Cutting occurred on 30 of these from mid-August 1993 to early-March 1994.

We used a fixed-radius, circular-plot technique (Verner 1985) to count birds during the breeding season before (1993) and two breeding seasons after (1994 and 1995) cutting. Each count station was visited 10 times during a season at approximately regular intervals between late-March and mid-July. Observers recorded all birds detected by sight and sound within a 100-m (328-foot) radius of the counting station during a 5-minute period. Aigner (1996) describes the selection of experimental units and counting procedures in detail.

Power Analysis

We selected 10 bird species, five residents and five breeding migrants, for our power analysis (*table 1*). Species were selected to represent a range of mean densities, as well as spatial and temporal variances in occurrence, although no extremely rare species were included.

Sample Size Limited by Cost

For the fixed budget optimization we used the procedure described by Neter and others (1990:992) for a completely randomized single-factor study with

Table 1—Standard deviations in population trend[1] among visits ($\hat{\sigma}_s$) and count stations ($\hat{\sigma}_s$), and optimal numbers of visits (m_{opt}) to minimize the variance of the treatment mean population trend for birds at Sierra Foothill Research and Extension Center, California.

Species	$\hat{\sigma}_s$	$\hat{\sigma}_u$	m_{opt}
Residents:			
Acorn woodpecker (*Melanerpes formicivorus*)	24.4	6.5	4
Plain titmouse (*Parus inornatus*)	24.0	3.7	7
Bewick's wren (*Thryomanes bewickii*)	14.6	3.6	4
Hutton's vireo (*Vireo huttoni*)	8.1	-	[2]-
Rufous-crowned sparrow (*Aimophila ruficeps*)	12.4	3.1	4
Breeding Migrants:			
Western kingbird (*Tyrannus verticalis*)	10.9	3.6	3
Ash-throated flycatcher (*Myiarchus cinerascens*)	15.6	-	[2]-
House wren (*Troglodytes aedon*)	10.6	4.6	2
Blue-gray gnatcatcher (*Polioptila caerulea*)	8.6	2.7	3
Orange-crowned warbler (*Vermivora celata*)	10.8	1.7	6
Σ All species:	44.2	11.0	4

[1] Population trend for a species is the mean difference between the number of birds counted in the season before cutting and each of the two seasons after cutting.
[2] Subsampling error > experimental error, so no estimates of σ_u or m_{opt} could be derived.

subsampling. Under this model, visits (*m*) are considered subsamples, and sample size (*n*) is equal to the number of count stations. For each species, our parameter of interest was the population trend, defined as the mean difference between the number of birds counted in the season before cutting and each of the two seasons after cutting. The procedure minimizes the variance of the treatment mean, subject to the cost constraint equation:

$$C = c_o + an(c_u + mc_s) \quad (1)$$

where C is total cost, c_o is any fixed cost, c_u is the cost of establishing a count station, c_s is the cost of visiting a count station, and a is the number of treatments. The resulting expression for the optimal number of visits is:

$$m_{\text{opt}} = \frac{\sigma_s}{\sigma_u}\sqrt{\frac{c_u}{c_s}} \quad (2)$$

where σ_s is the standard deviation in population trend among visits and σ_u is the standard deviation among count stations. From our experience, we estimated that the cost of visiting a count station is the same as establishing one, thus $c_s = c_u$, and equation (2) reduces to the ratio σ_s/σ_u. This estimate ignores the cost of applying a treatment. When a treatment must be applied, c_u will probably be much greater than c_s.

In equation (2), note that the optimal number of visits does not depend on total cost. Once m_{opt} has been calculated, only n is determined by total cost in equation (1). Thus, the calculation of the optimal number of visits does not require specifying a total cost, only the relative costs of establishing and visiting a station. For generality, we did not set a particular total cost and consequently computed only m_{opt} and not n.

When n is approximately >20 and the desired significance criterion is in the range 0.05 to 0.1, minimizing the variance of the treatment mean is approximately equivalent to maximizing power to detect a treatment effect. When n is small, maximum power may occur with n higher, and m lower than the optimal values to minimize the variance of the treatment mean. This is because when n is small, the increase in power from additional error degrees of freedom may outweigh the loss of power from having a larger variance.

Sample Size Limited by Logistical Constraints

To investigate how power improves with added visits when the number of count stations is fixed by constraints other than cost, we ran 10 separate power analyses for each bird species using data from all 60 count stations. We began by using data from a single visit and incrementally selected more visits with each subsequent analysis. Visits selected for each analysis were uniformly distributed across the breeding season, or as close as possible. In each case, we computed power to detect the effect of thinning on population trend in a single-factor analysis of covariance model (ANCOVA, Norušis 1992:35-54). Although this method of resampling was subjective and may have resulted in somewhat biased power estimates, it was adequate for our goal of obtaining a rough idea of how power improves with added visits.

Precutting count was used as a covariate in the model as a variance reduction technique. We observed an inherent tendency for points with high precutting counts to have negative population trends, and points with low or zero precutting counts to have positive trends.

In the power analyses, we set the effect size at 50 percent of the mean precutting count and used a significance criterion of 0.05. We chose 50 percent as the minimum biologically important effect size because many species had large among-year variation in total count. For example, we had 38 percent fewer detections of acorn woodpeckers in 1995 than in 1993 (Aigner, unpublished data).[5] We reasoned that thinning effects, to be biologically important, should exceed among-year variation in bird counts.

Power calculations were made using the computer program STPLAN (University of Texas System Cancer Center 1986). Because this program does not specifically provide for the use of a covariate, actual error degrees of freedom were one less than those used in the power calculations. Consequently, our power estimates are slightly liberal, although the difference should be insignificant.

Sample Size to Meet Power Requirements

For each species, we calculated sample sizes necessary to meet power requirements for the design described above. Because most studies are likely to

[5] Unpublished data on file at Rocky Mountain Research Station, Southwest Forestry Complex, 2500 South Pine Knoll Drive, Flagstaff, AZ 86001.

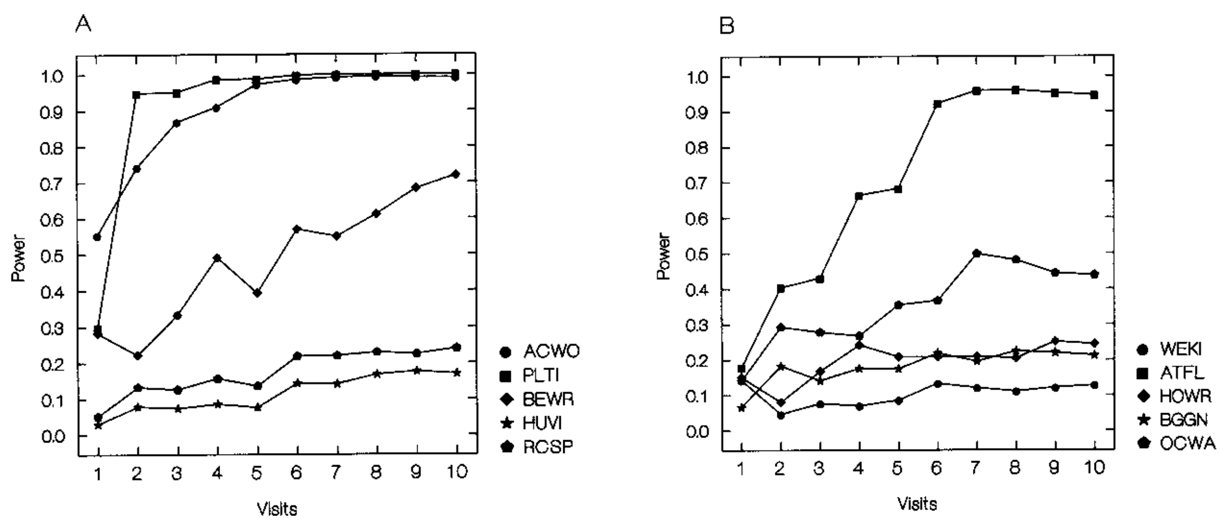
target several bird species, in these calculations we used a value for m to minimize the sum of the variance of the treatment mean for all 10 species. We computed sample sizes necessary to achieve power of 0.6, 0.7, and 0.8, with significance criteria of 0.05, 0.1, and 0.2 and an effect size equal to 50 percent of the mean precutting count. Sample size calculations were made using the computer program PC-SIZE (Dallal 1986). As with STPLAN, actual error degrees of freedom were one less than those used in the power calculations. Consequently, necessary sample sizes were slightly underestimated. The difference should be insignificant when the sample size per treatment level is >15.

Results

The optimal numbers of visits (m_{opt}) to minimize the variance of the treatment mean population trend ranged from two for the house wren to 7 for the plain titmouse (*table 1*). Four visits minimized the sum of the variances across all species excluding the Hutton's vireo and ash-throated flycatcher. We were unable to calculate m_{opt} for the Hutton's vireo and ash-throated flycatcher because subsampling error exceeded experimental error, so no estimates of σ_u could be derived (Neter and others 1990:997-998). This indicates that σ_s was large relative to σ_u, and m_{opt} would be large for these species if it could be estimated. Our estimates of m_{opt} can be easily modified for different cost structures by substituting appropriate values of c_s and c_u into equation (2) and using estimates of σ_s and σ_u from *table 1*.

When we fixed the number of count stations at 30 per treatment level, the increase in power associated with added visits varied among species (*fig. 1*). With only one visit, power was <0.6 for all species. For the acorn woodpecker, plain titmouse, and ash-throated flycatcher, increasing visits to 7 raised power to >0.9. In contrast, increasing visits did nothing to improve power for the western kingbird; power was greatest with only one visit. For the Hutton's vireo, rufous-

Figure 1—The effect of increasing visits on the statistical power to detect an effect of firewood cutting on population trends of five resident (A) and five breeding migrant (B) bird species at Sierra Foothill Research and Extension Center, California, when the number of count stations is fixed at 30 per treatment group. Effect size is 50 percent of the mean precutting count, and significance criterion is 0.05. Acronyms for species are ACWO = acorn woodpecker, PLTI = plain titmouse, BEWR = Bewick's wren, HUVI = Hutton's vireo, RCSP = rufous-crowned sparrow, WEKI = western kingbird, ATFL = ash-throated flycatcher, HOWR = house wren, BGGN = blue-gray gnatcatcher, and OCWA = orange-crowned warbler.



crowned sparrow, house wren, and blue-gray gnatcatcher, power increased slightly with increased visits, but was <0.3 even with 10 visits. The Bewick's wren and orange-crowned warbler showed intermediate increases in power. For all species, except the Bewick's wren, that showed increased power with increased visits, the increase in power leveled off after the sixth or seventh visit. For the Bewick's wren, power continued to increase almost linearly up to the 10th visit.

The number of count stations necessary to meet the specified power requirement varied among species by a factor of one-thousand (*table 2*). Sample sizes per treatment group necessary to achieve power = 0.8 to detect a 50 percent cutting effect with a significance criterion of 0.05 ranged from 14 for the plain titmouse to 920 for the western kingbird.

These sample-size requirements are for a two-tailed test of effects in a two-group comparison with a relatively stringent significance criterion. In *table 2*,

Table 2—Count stations per treatment group necessary to meet power requirements to detect the effect of thinning on bird population trends[1] at Sierra Foothill Research and Extension Center, California.

		Two-tailed significance criterion[2]		
Species (effect, S.D.)[3]	Power	0.05	0.1	0.2
Residents:				
Acorn woodpecker (46, 51)	0.6	16	12	8
	0.7	20	15	10
	0.8	24	19	14
Plain titmouse (68, 60)	0.6	9	7	5
	0.7	11	9	6
	0.8	14	11	8
Bewick's wren (22, 41)	0.6	36	27	18
	0.7	46	35	24
	0.8	58	45	33
Hutton's vireo (4, 28)	0.6	402	296	192
	0.7	510	386	267
	0.8	650	510	369
Rufous-crowned sparrow (12, 47)	0.6	143	105	69
	0.7	180	137	95
	0.8	229	180	131
Breeding Migrants:				
Western kingbird (6, 43)	0.6	580	420	273
	0.7	720	550	379
	0.8	920	730	530
Ash-throated flycatcher (26, 41)	0.6	26	19	13
	0.7	32	25	17
	0.8	41	32	23
House wren (11, 34)	0.6	93	69	45
	0.7	117	89	62
	0.8	148	117	85
Blue-gray gnatcatcher (7, 27)	0.6	132	97	63
	0.7	165	126	87
	0.8	210	165	121
Orange-crowned warbler (13, 37)	0.6	81	60	39
	0.7	102	78	54
	0.8	129	102	74

[1]Population trend defined in *table 1*.
[2]For a significance criterion of 0.05 in a one-tailed test, use the 0.1 column; for a significance criterion of 0.1 in a one-tailed test, use the 0.2 column.
[3]Effect is 50 percent of the mean precutting count. Units are birds counted per 100 count stations.

sample sizes for one-tailed tests with significance criteria of 0.05 and 0.1 are equivalent to the two-tailed results with significance criteria of 0.1 and 0.2, respectively. For all species, sample size to achieve power = 0.8 in a one-tailed test with a significance criterion of 0.1 is approximately half of that required in a two-tailed test with a significance criterion of 0.05.

Discussion

Our estimates of the optimal allocation of sampling effort to count stations and visits varied greatly among species. The biological factors underlying this variation are probably complex. For a given cost structure, m_{opt} is determined by the ratio of within-season temporal (σ_s) to spatial (σ_u) variability in population trend. Temporal and spatial variability in population trend are not correlated with temporal and spatial variability in occurrence. For example, the blue-gray gnatcatcher is a species with high spatial variability in occurrence, and it tends to reoccupy the same sites year after year. Occupied and unoccupied sites have zero or near-zero changes in count among years, and consequently the spatial variability in population trend is low. In general, such site fidelity in species should contribute to reducing σ_u and increasing m_{opt}.

For migrant breeders, within-season temporal variability in population trend could be affected by among-year differences in arrival times. Consider, for example, a migratory species that arrived and left earlier in each of the two seasons postcutting than in the precutting season. Even if overall numbers remained constant, the population trend would be positive early in the season and negative later in the season. Population trend, although variable in time, would be uniform over all count stations. In this way, temporal variability would be exaggerated relative to spatial variability.

Despite these sources of variability, m_{opt} for all species was ≥ 2. Ralph and others (1993) recommended sampling a count station only once during a season, pointing out that if one is to make a fixed *nm* observations in a specified period, it is better statistically to count at *nm* stations than to visit *n* stations *m* times (where $m \geq 2$). Although this observation is true, it is misleading because it fails to consider cost. Unless there is no cost associated with establishing a count station, perhaps possible only if count stations have been established in a previous study, visiting 15 count stations twice will be cheaper than visiting 30 count stations once. When the cost of establishing a count station is high, as where an experimental treatment must be applied, the statistical benefit of making more visits at fewer count stations grows. Furthermore, when the number of count stations is constrained by logistics or limited potential for experimental treatments, increasing the number of visits can increase power to acceptable levels.

Buskirk and McDonald (1995), using data from point counts in a deciduous woodland in Indiana, and Smith and others (1995), using data from bottomland hardwood forests in the Mississippi alluvial valley, came to identical conclusions that three or fewer visits per season should maximize the efficiency of point counts. Using a bootstrap, the authors selected these optima to maximize the cumulative number of species detected or the cumulative number of individuals detected. Although their recommendations are similar to our overall m_{opt} of four, the agreement seems largely coincidental. Both recommendations were based on an implicit assumption that no cost was associated with establishing a count station. Furthermore, maximizing the cumulative number of species or individuals detected should have little relationship to maximizing the power to detect a specified effect on population trend for a particular species.

For a two-tailed test with a significance criterion of 0.05, sample sizes necessary to attain power = 0.8 were prohibitively large for nearly half the species in our study. Few studies that we are aware of have had anywhere near 210 to 920 count stations per treatment level. Required sample sizes were largest for the most uncommon species. This is particularly problematic, as some of these species were uncommon because they were habitat specialists. Given that habitat specialists may be more sensitive to environmental change than habitat generalists (Tellería and Santos 1995), experiments to detect environmental impacts on birds will have most difficulty meeting power requirements for species most likely to be affected.

When only declines in density are of concern, necessary sample size may be reduced by using one-tailed tests for effects. This may be appropriate when a study is focussed on only one or two sensitive species. However, if an entire avifauna is under study, both declines and increases in density are likely to be of interest. For exotic species, like the European starling (*Sturnus vulgaris*), or brood parasites, like the brown-headed cowbird (*Molothrus ater*), increases in density are as important as decreases. Required sample sizes may also be reduced by relaxing significance criteria. In conservation biology, where the cost of failing to detect an effect may be the extinction of the species in question, 0.1 may replace 0.05 as a generally accepted significance criterion.

Required sample sizes may be further reduced by accepting a lower probability of rejecting the null hypothesis when it is false (i.e., lessening power). Currently, there is no generally accepted level for the power of a test. Clearly, there is no justification for proceeding with a study if power <0.5, but at what value power becomes acceptable is unclear.

We emphasize that investigators must clearly define study goals and parameters of interest to be able to optimize design and meet power requirements. Sample sizes to meet power requirements and optimal allocation of sampling effort vary widely among species. Most studies of impacts on birds in oak woodlands will probably focus on several species, if not the entire avifauna. This complicates the optimization of sampling effort and determination of sample size. At a minimum, investigators must select a sample size that will provide adequate power for most of the species of interest. Furthermore, power analysis and optimization of sampling effort require that the investigator has defined a parameter of interest. Clearly, it is not enough to specify that counts of birds are of interest. Optimization of sampling effort will undoubtedly vary depending on whether the population parameter is the cumulative number of species detected, the number of individuals counted of a particular species, or the difference in a count between time periods. Thus, optimization of study design requires that specific parameters of interest and statistical hypothesis tests are clearly defined.

Ideally, investigators should conduct pilot studies in order to obtain the variance components necessary for preliminary power analyses. However, for almost any study it would be prohibitively expensive to collect the information necessary to evaluate the full range of possible study designs. For this reason, we think that great benefit would come from more regular publication of design evaluations after studies are completed. At least cursory design evaluations should be included in all published studies that use statistical hypothesis tests.

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References

Aigner, Paul A. 1996. **Effects of firewood harvesting on avian abundance and guild structure in a California oak-pine woodland**. Flagstaff: Northern Arizona University; 117 p. M.S. thesis.

Block, William M. 1989. **Spatial and temporal patterns of resource use by birds in California oak woodlands**. Berkeley: University of California; 364 p. Ph.D. dissertation.

Buskirk, William H.; McDonald, Jennifer L. 1995. **Comparison of point count sampling regimes for monitoring forest birds**. In: Ralph, C. John; Sauer, John R.; Droege, Sam, technical editors. Monitoring bird populations by point counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 25-34.

Cohen, Jacob. 1988. **Statistical power analysis for the behavioral sciences**. 2d ed. Hillsdale, NJ: Lawrence Erlbaum Associates; 567 p.

Dallal, Gerard E. **PC-SIZE: A program for sample size determinations** [Computer program]. 1986. 53 Beltran St., Malden, MA 02148.

deCalesta, David S. 1994. **Effect of white-tailed deer on songbirds within managed forests in Pennsylvania**. Journal of Wildlife Management 58(4): 711- 718.

Neter, John; Wasserman, William; Kutner, Michael H. 1990. **Applied linear statistical models: regression, analysis of variance, and experimental designs**. 3d ed. Homewood, IL: Irwin; 1181 p.

Norušis, Marija J. 1992. **SPSS/PC+, Advanced Statistics, Version 5.0**. Chicago, IL: SPSS Inc.; 481 p.

Osenberg, Craig W.; Schmitt, Russell J.; Holbrook, Sally J.; Kahlil, E. Abu-Saba; Flegal, A. Russell. 1994. **Detection of environmental impacts: natural variability, effect size, and power analysis**. Ecological Applications 4(1): 16-30.

Ralph, C. John; Geupel, Geoffrey R.; Pyle, Peter; Martin, Thomas E.; DeSante, David F. 1993. **Handbook of field methods for monitoring landbirds**. Gen. Tech. Rep. PSW-GTR-144. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 41 p.

Smith, Winston P.; Twedt, Daniel J.; Cooper, Robert J.; Wiedenfeld, David A.; Hamel, Paul B.; Ford, Robert P. 1995. **Sample size and allocation of effort in point count sampling of birds in bottomland hardwood forests**. In: Ralph, C. John; Sauer, John R.; Droege, Sam, technical editors. Monitoring bird populations by point counts. Gen. Tech. Rep. PSW-GTR-149. Albany, CA: Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture; 7-17.

Tellería, J.L.; Santos, T. 1995. **Effects of forest fragmentation on a guild of wintering passerines: the role of habitat selection**. Biological Conservation 71(1): 61-67.

Thompson, Steven K. 1992. **Sampling**. New York: John Wiley & Sons; 343 p.

University of Texas System Cancer Center. **STPLAN** [Computer program]. 1986. M.D. Anderson Hospital and Tumor Institute, Department of Biometrics, Box 237, 1515 Holcombe Blvd., Houston, TX 77030.

Verner, Jared. 1985. **Assessment of counting techniques**. Current Ornithology 2: 247-302.

Wilson, Christopher W.; Masters, Ronald E.; Bukenhofer, George A. 1995. **Breeding bird response to pine-grassland community restoration for red-cockaded woodpeckers**. Journal of Wildlife Management 59(1): 56-67.