*The Condor* 108:691–699
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# COMBINING BREEDING BIRD SURVEY AND DISTANCE SAMPLING TO ESTIMATE DENSITY OF MIGRANT AND BREEDING BIRDS

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*Abstract.* We combined Breeding Bird Survey point count protocol and distance sampling to survey spring migrant and breeding birds in Vicksburg National Military Park on 33 days between March and June of 2003 and 2004. For 26 of 106 detected species, we used program DISTANCE to estimate detection probabilities and densities from 660 3-min point counts in which detections were recorded within four distance annuli. For most species, estimates of detection probability, and thereby density estimates, were improved through incorporation of the proportion of forest cover at point count locations as a covariate. Our results suggest Breeding Bird Surveys would benefit from the use of distance sampling and a quantitative characterization of habitat at point count locations. During spring migration, we estimated that the most common migrant species accounted for a population of 5000–9000 birds in Vicksburg National Military Park (636 ha). Species with average populations of >300 individuals during migration were: Blue-gray Gnatcatcher (*Polioptila caerulea*), Cedar Waxwing (*Bombycilla cedrorum*), White-eyed Vireo (*Vireo griseus*), Indigo Bunting (*Passerina cyanea*), and Ruby-crowned Kinglet (*Regulus calendula*). Of 56 species that bred in Vicksburg National Military Park, we estimated that the most common 18 species accounted for >8150 individuals. The six most abundant breeding species, Blue-gray Gnatcatcher, White-eyed Vireo, Summer Tanager (*Piranga rubra*), Northern Cardinal (*Cardinalis cardinalis*), Carolina Wren (*Thryothorus ludovicianus*), and Brown-headed Cowbird (*Molothrus ater*), accounted for >5800 individuals.

*Key words: breeding bird survey, density, detection probability, distance sampling, loess bluff forest, migration.*

## Combinación de Censos de Aves Reproductivas y Muestreos con Distancia para Estimar la Densidad de Aves Migratorias y Reproductivas

*Resumen.* Combinamos datos de censos de aves reproductivas realizados mediante un protocolo de conteos por punto con muestreos en que se registra la distancia para censar las aves migratorias de primavera y las residentes en Vicksburg National Military Park durante 33 días entre marzo y junio de 2003 y 2004. Para 26 de las 106 especies detectadas, empleamos el progama DISTANCE para estimar las probabilidades de detección y las densidades a partir de 660 conteos por punto de 3 minutos de duración, en los que las detecciones fueron registradas en cuatro rangos de distancia alrededor de los puntos de conteo. Para la mayoría de las especies, los estimados de la probabilidad de detección (y por lo tanto de la densidad) se mejoraron mediante la incorporación de la proporción de cobertura boscosa en el sitio de conteo como una covariable. Nuestros resultados sugieren que los censos de aves reproductivas se beneficiarían del uso de muestreos con distancia y de caracterizaciones cuantitativas del hábitat en los puntos de conteo. Durante la migración de primavera, estimamos que las especies de migrantes más comunes representaron una población de 5000 a 9000 aves en Vicksburg National Military Park (636 ha). Las especies con tamaños poblacionales promedio mayores que 300 individuos durante la migración fueron *Polioptila caerulea*, *Bombycilla cedrorum*, *Vireo griseus*, *Passerina cyanea* y *Regulus calendula*. Estimamos que más de 8150 de los individuos correspondieron a las 18 especies más comunes entre las 56 que se reprodujeron en el área de estudio. Más de 5800 individuos pertenecieron a las seis especies reproductivas más abundantes: *P. cerulea, V. griseus, Piranga rubra*, *Cardinalis cardinalis*, *Thryothorus ludovicianus* y *Molothrus ater*.

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## INTRODUCTION

Estimations of avian abundance and density provide a foundation for investigating population sizes and habitat associations (Norvell et al. 2003). Point counts are one of the most common survey methods for monitoring birds (Ralph et al. 1995) and are used to monitor populations at local and continental scales (Robbins and Van Velzen 1967, Pardieck and Sauer 2000). Because probability of detection is not estimated when using standard point count methods (Norvell et al. 2003), point counts provide an estimate of relative abundance rather than density (Pendleton 1995). Abundance indices are not comparable among species because of documented differences in detectability (Norvell et al. 2003). Nevertheless, indices of relative abundance are generally accepted as comparable among surveys for the same species if variations in detectability are controlled through standardization of methods (Norvell et al. 2003, but see Anderson 2001).

Sources of variation in detectability are numerous, including differences among observers, environments, and intrinsic characteristics of bird species. Even so, if point counts are combined with distance sampling it is possible to estimate detection probabilities and thereby estimate avian densities (Rosenstock et al. 2002). Because distance sampling reduces bias in estimates of avian populations, these data are more reliable for conservation planning and assessment, thus distance sampling (Buckland et al. 2001) has recently become more widely used to assess avian populations (Norvell et al. 2003, Harrison and Kilgo 2004). Alternative methods that also estimate the probability of detection, such as double-observer (Nichols et al. 2000) or removal methods (Farnsworth et al. 2002), have been less well received, as they are generally regarded as time consuming, expensive, or logistically difficult. With a few exceptions (DeSante 1981, 1986), field application of distance sampling methods has worked well (Jones et al. 2000, Norvell et al. 2003).

Although not independent, repeated sampling at the same point count location provides a more precise estimate of the number of species and individuals at that point (Farnsworth et al. 2002, Rosenstock et al. 2002). Furthermore, multiple counts at the same point count location and detection of the same individuals on multiple days do not violate the assumptions of distance sampling, as long as individuals are not unknowingly detected more than once from the same point during the same count (Buckland et al. 2001). Thus, point count survey methods, which may employ repeated sampling at the same location, can be safely combined with distance sampling to assess bird density and estimate population size.

A Breeding Bird Survey (BBS) is a standardized roadside survey method that employs a series of point counts to assess bird abundance (Robbins and Van Velzen 1967). In recent decades, data from Breeding Bird Surveys have been used to assess changes in bird populations (Sauer et al. 2004). BBS protocol requires skilled observers to record all birds that they detect within 400 m (0.25 mi) at 50 points spaced at 0.8 km (0.5 mi) intervals without recording distance-to-bird data. In this paper we sought to assess the merits of combining standard point count protocols, as employed for Breeding Bird Surveys, and distance sampling for surveying bird populations.

## METHODS

### STUDY AREA

We established a bird survey route along Union, Connecting, and Confederate Avenues in Vicksburg National Military Park (VNMP), Warren County, southwestern Mississippi (32°21′N, 90°50′W; Fig. 1). Vicksburg National Military Park, recognized as an Important Bird Area by the National Audubon Society, is characterized by highly erodible loess bluffs and mesic upland hardwood forests. High public visitation, however, has warranted maintaining some areas of the park (e.g., surrounding historic monuments and scenic vistas) in herbaceous vegetation through periodic mowing or burning.

### SURVEY METHODS

We surveyed birds in VNMP from 27 March through 27 June 2003 and from 26 March through 7 June 2004 using Breeding Bird Survey (BBS) methods. Specifically, we used a mini-BBS route that consisted of 20 3-min roadside point counts (compared to 50 counts on a standard BBS route), each separated by 0.8 km (Wiley 2006). These surveys resulted in

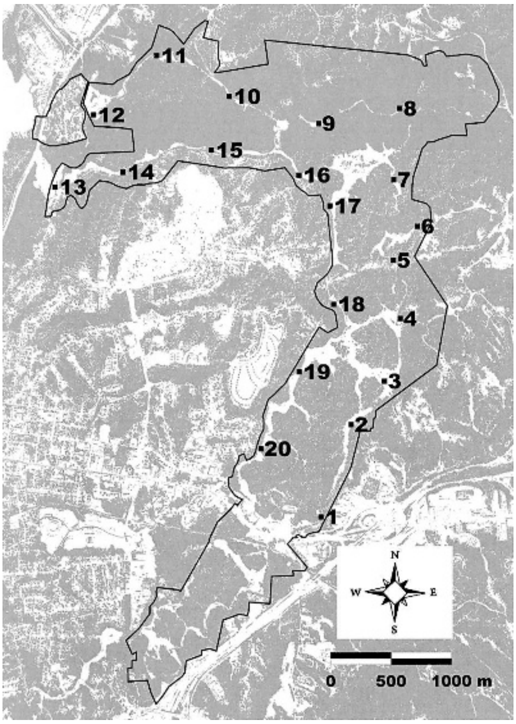


FIGURE 1. Forest cover (gray shading) and point count locations along a mini-Breeding Bird Survey route in Vicksburg National Military Park, Vicksburg, southwestern Mississippi.

660 3-min point counts during spring and summer 2003 and 2004, wherein the locations of birds were recorded within four distance annuli. We employed distance annuli because of the ease of assigning detected individuals to annuli, as opposed to the difficulty of assigning precise distances to detected birds, particularly when individuals were aurally detected in forested habitats.

Although BBS protocol requires that each point be visited only once during the breeding season, we surveyed each point 10 times during spring migration 2003 (27 March–2 May) and 15 times during spring migration 2004 (26 March–5 May). We also conducted surveys on four mornings during each of the 2003 (7 May–27 June) and 2004 (10 May–7 June) breeding seasons.

Points were surveyed in the same order each day, following BBS protocol. We deviated from BBS protocol by repeatedly sampling point locations within a breeding season, but these data may be analogous to data collected on BBS routes over multiple survey years. We conducted surveys within the first 2.5 hr after sunrise and recorded the species and number of all birds seen or heard during the 3-min sampling period. We estimated and recorded the distance to each individual detected within four distance annuli: 0–25 m, >25–50 m, >50–100 m, and >100 m. We estimated detection distance by pacing distances from point count centers to various objects in the count circles and periodically recalibrated distance estimates throughout the study period. Although some point count locations were not heavily forested, we detected few birds beyond 150 m, with the exception of raptors, vultures, and corvids. Flyovers were recorded separately and not used to estimate density. We deposited all data from our point counts in the North American bird point count database (Wimer 2006).

### DENSITY ESTIMATION

We used program DISTANCE (Thomas et al. 2005) to estimate songbird density using detection probabilities estimated from categorical distance-to-bird data. We fit detection functions for uniform models with cosine and simple polynomial expansions as well as half-normal models with cosine and hermite polynomial expansions. We pooled data across years to increase the number of detections. Even so, because a minimum number of 60–100 detections is recommended to estimate density with a reasonable degree of accuracy using program DISTANCE, we were unable to estimate density for all species. We included analyses with 50–59 detections, acknowledging the lower reliability of these results. We analyzed data using all distance annuli but truncated data when we recorded few (<5) detections in the outermost annuli. A slight amount of precision may be lost through truncation; however precision is more often increased because fewer parameters are required to model the detection function. More importantly, truncation often reduces bias or improves precision of density estimates by making the data easier to model (Buckland et al. 2001).

Within the context of the normal and half-normal models and their expansions identified above, we estimated a constant detection probability among habitat conditions (i.e., a model with no covariates). Because bird distributions were likely influenced by habitat conditions, we also modeled a variable detection probability by using the proportion of forest cover as a covariate. We calculated the proportion of forest cover within 150 m of point counts using digital aerial photography (1 m resolution) using geographic information system software (TNT–MIPS, Microimages, Lincoln, Nebraska). For analysis, we categorized forest cover as either high (≥65%) or low (<65%). We selected the best-fitting model based on Akaike's information criterion ($AIC_c$; Akaike 1974, Burnham and Anderson 2002), chi-square model-fit statistics, and visual inspection of the detection probability and probability density plots (Buckland et al. 2001).

As most resident species had established territories and were nesting during our migration survey period, we combined data from all 33 survey dates for estimation of detection probabilities and density for resident species. We calculated detection probability and density of migrant birds during migration using data from the migratory period. Similarly, we calculated detection probabilities and densities for breeding migrants using data only from the breeding season.

To estimate the daily mean number of individuals in VNMP, we extrapolated species-specific estimates of density within each forest cover category to population estimates for the area of VNMP having the same forest cover. For species for which we were only able to estimate density within one forest cover category, we calculated the number of individuals only within the area of VNMP in that same forest cover category. Cedar Waxwings (*Bombycilla cedrorum*) are gregarious and therefore we estimated the number of groups (clusters) encountered, rather than individuals, and extrapolated to total individuals based on mean cluster size. Extrapolation of density estimates to population estimates provides values that are easily interpreted by land managers and aids in assessment of population objectives identified in avian conservation plans.

For comparison with density estimates determined using distance-based analyses, we calculated a relative abundance for each species uncorrected for detection probabilities. Relative abundances were calculated from data based on detections from the 25 survey days during spring migration for migrant species, all 33 survey days for permanent resident species, and eight survey days for breeding migrant species within a radius of 50 or 100 m that included >70% of all detections for the species.

## RESULTS

We detected 106 species during point counts in Vicksburg National Military Park, which at a 150 m detection distance surveyed >20% of the 636 ha contained in VNMP (Fig. 1). Of these species, we had sufficient detections to estimate detection probabilities and densities for only 14 migratory species during migration (Table 1), eight migratory species during the breeding season, and 10 resident breeding species (Table 2). Of our 20 count locations, 13 were within the 522 ha of VNMP that had ≥65% forest cover, and the remaining seven count locations were within the 114 ha where forest cover was <65%. Proportion of forest cover was an important predictor of detection probability and density for *en-route* migrating songbirds (10 of 14 species) but had less influence on the detection probability of resident species (five of 10 species) and migrant species that bred in VNMP (two of eight species).

During spring migration, we estimated that the 14 species for which we were able to calculate densities accounted for >7000 individuals (Table 1). The number of migrants, however, varied daily with bird arrivals and departures. The 90% confidence interval of our population estimate (5000–9000 total birds; Table 1) may reflect this fluctuation in numbers in VNMP during migration. We estimated a breeding population of >8150 individuals of the 18 most common species in VNMP (Table 2). The six most abundant breeding species, Blue-gray Gnatcatcher, White-eyed Vireo, Summer Tanager (*Piranga rubra*), Northern Cardinal (*Cardinalis cardinalis*), Carolina Wren (*Thryothorus ludovicianus*), and Brown-headed Cowbird (*Molothrus ater*), accounted for >5800 individuals.

Relative abundance and estimated number of birds during migration were >50% lower than our estimates that used distance sampling protocols (Table 1). For the eight most common migratory species that bred in VNMP, the number of individuals estimated without correction for detection probability was ≥64% lower then our estimates that were corrected for

TABLE 1. Density estimates (birds per km$^2$; $\hat{D}$) and corresponding coefficients of variation (CV) and 90% confidence intervals ($CI_{90\%}$) generated by program DISTANCE based on the number of birds detected ($n$) and their detection probabilities ($P_a$) during 500 point counts along a mini-Breeding Bird Survey route during spring migration in 2003 and 2004 in Vicksburg National Military Park (636 ha), Warren County, southwestern Mississippi. Densities are estimated separately for high (≥65%; H) and low (<65%; L) forest cover when possible, and estimates are extrapolated to a "park-wide" population estimate of the number of individuals ($\hat{N}$). For comparison, relative abundances ($\hat{A}_{rel}$) uncorrected for detection probability and estimated number of individuals ($\hat{N}$) are presented for distance annuli that encompassed >70% of species detections.

| Species | % forest | $n$ | $P_a$ | Density $\hat{D}$ | Density CV | Density $CI_{90\%}$ | $\hat{N}$ | Relative abundance $\hat{A}_{rel}$ | Relative abundance $\hat{N}$ |
|---|---|---|---|---|---|---|---|---|---|
| Great Crested Flycatcher | — | 82 | 0.30 | 7.8 | 23.0 | 5.3–11.3 | 50 | 4.1 | 26 |
| *Myiarchus crinitus* | | | | | | | | | |
| White-eyed Vireo | H | 347 | 0.09 | 164.6 | 9.1 | 141.7–191.3 | 925 | 26.0 | 165 |
| *Vireo griseus* | L | 100 | 0.14 | 56.0 | 24.8 | 36.7–85.5 | | | |
| Red-eyed Vireo | H | 184 | 0.21 | 38.0 | 23.9 | 25.7–56.1 | 198 | 12.7 | 81 |
| *Vireo olivaceous* | L | 24 | — | | | | | | |
| Ruby-crowned Kinglet | H | 81 | 0.14 | 68.2 | 19.4 | 49.2–94.4 | 356 | 26.2 | 167 |
| *Regulus calendula* | L | 52 | 0.31 | 24.1 | 25.9 | 15.4–37.6 | | | |
| Blue-gray Gnatcatcher | H | 368 | 0.10 | 433.1 | 11.7 | 353.8–530.2 | 2446 | 124.3 | 791 |
| *Polioptila caerulea* | L | 184 | 0.16 | 163.4 | 12.3 | 115.5–231.1 | | | |
| Cedar Waxwing | H | 51[a] | 0.17 | 10.1 | 21.5 | 7.1–14.5 | 1368 | 108.2 | 688 |
| *Bombycilla cedrorum* | L | 51[a] | 0.33 | 9.5 | 17.1 | 7.0–12.8 | | | |
| Northern Parula | — | 110 | 0.42 | 7.5 | 21.9 | 5.1–10.8 | 48 | 5.5 | 35 |
| *Parula americana* | | | | | | | | | |
| Tennessee Warbler | H | 147 | 0.15 | 43.7 | 30.2 | 26.8–71.3 | 267 | 11.9 | 76 |
| *Vermivora peregrina* | L | 56 | 0.13 | 33.9 | 32.4 | 19.5–58.9 | | | |
| Yellow-rumped Warbler | — | 107 | 0.27 | 24.9 | 27.0 | 15.8–39.2 | 175 | 19.3 | 123 |
| *Dendroica coronata* | | | | | | | | | |
| Kentucky Warbler | H | 69 | 0.49 | 6.2 | 38.0 | 3.4–11.4 | 32 | 3.9 | 25 |
| *Oporornis formosus* | L | 6 | — | | | | | | |
| Hooded Warbler | H | 297 | 0.28 | 45.6 | 19.8 | 32.9–63.1 | 252 | 20.7 | 132 |
| *Wilsonia citrina* | L | 85 | 0.57 | 12.1 | 41.6 | 6.1–23.7 | | | |
| Summer Tanager | H | 166 | 0.15 | 48.7 | 13.2 | 39.0–60.7 | 288 | 15.1 | 96 |
| *Piranga rubra* | L | 96 | 0.26 | 29.4 | 22.1 | 19.9–43.4 | | | |
| Indigo Bunting | — | 249 | 0.11 | 63.9 | 14.2 | 50.4–80.9 | 406 | 14.5 | 92 |
| *Passerina cyanea* | | | | | | | | | |
| Orchard Oriole | H | 82 | 0.12 | 30.1 | 29.3 | 18.5–48.9 | 191 | 10.5 | 67 |
| *Icterus spurious* | L | 115 | 0.32 | 29.3 | 17.7 | 21.7–39.7 | | | |
| Total | | | | | | | 7002 | | 2564 |

[a] Number of clusters (groups).

TABLE 2. Density estimates (birds per km$^2$; $\hat{D}$) and corresponding coefficients of variation (CV) and 90% confidence intervals ($CI_{90\%}$) generated by program DISTANCE based on the number of birds detected ($n$) and their detection probabilities ($P_a$) during 160 point counts for migrants or 660 point counts for residents (denoted by superscripted a) along a mini-Breeding Bird Survey route during spring migration in 2003 and 2004 in Vicksburg National Military Park (636 ha), Warren County, southwestern Mississippi. Densities are estimated separately for high (≥65%; H) and low (<65%; L) forest cover when possible, and estimates are extrapolated to a "park-wide" population estimate of the number of individuals ($\hat{N}$). For comparison, relative abundances ($\hat{A}_{rel}$) uncorrected for detection probability and estimated number of individuals ($\hat{N}$) are presented for distance annuli that encompassed >70% of species detections.

| | | | | Density | | | | Relative abundance | |
|---|---|---|---|---|---|---|---|---|---|
| Species | % forest | $n$ | $P_a$ | $\hat{D}$ | CV | $CI_{90\%}$ | $\hat{N}$ | $\hat{A}_{rel}$ | $\hat{N}$ |
| Yellow-billed Cuckoo *Coccyzus americanus* | — | 75 | 0.22 | 30.4 | 28.3 | 19.2–48.2 | 193 | 10.1 | 64 |
| Red-bellied Woodpecker[a] *Melanerpes carolinus* | — | 494 | 0.48 | 21.9 | 9.5 | 18.6–25.7 | 139 | 15.0 | 95 |
| Downy Woodpecker[a] | H | 70 | 0.15 | 15.2 | 23.0 | 10.3–22.4 | 79 | 4.5 | 29 |
| *Picoides pubescens* | L | 37 | — | | | | | | |
| Acadian Flycatcher *Empidonax virescens* | – | 57 | 0.26 | 44.3 | 30.5 | 26.6–73.8 | 282 | 11.3 | 72 |
| White-eyed Vireo *Vireo griseus* | – | 134 | 0.09 | 130.2 | 15.4 | 100.7–168.2 | 827 | 23.7 | 151 |
| Red-eyed Vireo | H | 73 | 0.19 | 52.0 | 18.3 | 38.4–70.5 | 271 | 13.7 | 87 |
| *Vireo olivaceous* | L | 7 | — | | | | | | |
| Carolina Chickadee[a] | H | 203 | 0.10 | 68.7 | 20.7 | 48.9–96.4 | 376 | 11.6 | 74 |
| *Poecile carolinensis* | L | 72 | 0.28 | 15.6 | 25.6 | 9.9–24.3 | | | |
| Tufted Titmouse[a] | H | 349 | 0.29 | 39.3 | 15.8 | 30.1–51.1 | 216 | 14.3 | 91 |
| *Baeolophus bicolor* | L | 108 | 0.68 | 9.8 | 28.5 | 6.0–15.9 | | | |
| Carolina Wren[a] *Thryothorus ludovicianus* | – | 969 | 0.25 | 84.5 | 14.9 | 66.1–107.9 | 537 | 35.0 | 223 |
| Blue-gray Gnatcatcher | H | 75 | 0.07 | 412.8 | 17.6 | 30.8–55.4 | 2156 | 85.1 | 541 |
| *Polioptila caerulea* | L | 38 | — | | | | | | |
| Northern Mockingbird[a] *Mimus polyglottos* | – | 115 | 0.44 | 5.6 | 38.1 | 2.9–10.5 | 36 | 3.7 | 24 |
| Hooded Warbler *Wilsonia citrina* | — | 55 | 0.17 | 28.8 | 23.5 | 19.5–42.4 | 183 | 10.1 | 65 |
| Summer Tanager *Piranga rubra* | — | 95 | 0.10 | 88.8 | 14.9 | 69.4–113.6 | 565 | 15.9 | 101 |
| Northern Cardinal[a] *Cardinalis cardinalis* | — | 1224 | 0.14 | 182.3 | 7.0 | 162.8–205.5 | 1163 | 43.8 | 279 |
| Indigo Bunting *Passerina cyanea* | — | 95 | 0.12 | 68.9 | 19.1 | 50.3–94.3 | 438 | 16.1 | 102 |

TABLE 2. Continued.

| Species | % forest | $n$ | $P_a$ | Density $\hat{D}$ | CV | $CI_{90\%}$ | $\hat{N}$ | Relative abundance $\hat{A}_{rel}$ | $\hat{N}$ |
|---|---|---|---|---|---|---|---|---|---|
| Eastern Towhee[a] | H | 75 | 0.16 | 15.9 | 28.2 | 9.9–25.3 | 83 | 4.0 | 25 |
| *Pipilo erythrophthalmus* | L | 34 | — | | | | | | |
| Brown-headed Cowbird[a] | H | 397 | 0.13 | 99.2 | 18.7 | 72.9–134.7 | 564 | 23.8 | 151 |
| *Molothrus ater* | L | 160 | 0.24 | 41.1 | 17.3 | 30.3–55.7 | | | |
| House Sparrow[a] | – | 108 | 0.18 | 13.1 | 61.9 | 4.9–34.8 | 83 | 3.6 | 23 |
| *Passer domesticus* | | | | | | | | | |
| Total: Migrants (8 species) | | | | | | | 4915 | | 1183 |
| Residents (10 species) | | | | | | | 3276 | | 1014 |

detection probability. Similarly, population estimates for eight of the 10 resident species were >50% lower when uncorrected for detection probability (Table 2).

## DISCUSSION

We encountered few difficulties when combining standard BBS monitoring and distance sampling for estimation of bird densities and populations. Data from our mini-Breeding Bird Surveys provided a representative inventory of migratory and breeding species, as well as density estimates for 26 common species migrating through or breeding in Vicksburg National Military Park.

Although we followed BBS protocol for data collection, we restricted our analyses to birds recorded within 150 m of the observer as few individuals, with the exception of raptors, vultures, and corvids, were detected beyond this distance. The current BBS data collection protocol does not provide for collection or analysis of data in distance annuli. However, we made only minor modifications to the standard BBS data collection technique to allow for subsequent application of analyses to estimate detection probabilities.

In following BBS protocol, we used the roads in VNMP for establishing survey locations, which were therefore not randomly distributed across the landscape. By conducting a mini-BBS route and surveying points in the same order each day, our survey was subject to the same biases encountered on standard BBS routes, which allows for the comparison of results using similar methodology. Surveying only roadsides overestimates the abundance of edge species, while underestimating species that avoid forest edges. We attempted to correct for this bias through incorporating the proportion of forest cover at each point count location as a covariate. We were unable to conduct random or systematic point counts in contiguous forests due to difficult terrain (i.e., steep ravines) and logistical constraints; however, such surveys would provide a valuable comparison of detection probability and density between survey methods and additional information on species that avoid edges.

Including a covariate that characterized habitat conditions (i.e., proportion of forest cover) improved our estimates of detectability and density. Currently, BBS protocol does not account for variability in habitat conditions among point count locations. However, advances in global positioning systems (GPS), remote sensing, and geographic information system (GIS) technology make possible concurrent or periodic quantitative characterization of the habitat at each point count location along BBS routes. We suggest that this information would result in increased reliability of BBS data.

We compared relative abundances derived from standard BBS protocol to estimates of density that were obtained by correcting for the probability of detection using distance sampling. We found that population estimates derived from uncorrected data markedly underestimated population estimates derived from data corrected for detection probability during the migration and the breeding season, with most species underestimated by >50%. Our comparisons of densities corrected for detection probability and uncorrected estimates of relative abundance were conservative, in that we limited our data analysis to the distance interval in which >70% of detections occurred. Extrapolation of the number of detections to relative abundances based on the full 400 m radius employed for BBS surveys would greatly exacerbate differences between densities corrected for detection probability and uncorrected estimates of abundance.

In the United Kingdom, an annual bird monitoring system (analogous to the BBS in North America) has had promising results combining distance sampling with line transect surveys to calculate habitat-specific density and population estimates on a national scale. Newson et al. (2005) highlighted the superiority of this methodology for producing population estimates based on avian density and the abundance of habitat compared with previously used methods, such as the Common Bird Census (Marchant et al. 1990), which did not incorporate distance sampling. However, they pointed out that surveys of species that flock during the breeding season, or are not strongly territorial, could be biased if detectability is not strongly correlated with flock size.

Because estimates of relative abundance are biased when uncorrected for detection probability, combining distance sampling with BBS protocol across a broad scale, such as all BBS routes within a Bird Conservation Region, physiographic region, or state, could greatly enhance our understanding of bird densities and population trends for many species. Unfortunately, because rare species are infrequently encountered on BBS routes, distance sampling may not improve our understanding of these species.

## ACKNOWLEDGMENTS

We thank Kurt Foote for assistance in facilitating our research. We are also indebted to Stephen J. Dinsmore, Mark Smith, and Tiago Marques for assistance with program DISTANCE. This paper greatly benefited from the editorial comments of Stephen Buckland, Grey Pendleton, David Dobkin, and one anonymous reviewer.

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