# Comparison of Point Count Sampling Regimes for Monitoring Forest Birds[1]

**William H. Buskirk and Jennifer L. McDonald**[2]

**Abstract:** A set of 255 counts was compiled for 13 points using 10-minute periods subtallied at 3 and 6 minutes. The data from each point were subsampled using combinations of count periods, numbers, and schedules to compare the effectiveness of these different regimes at per point coverage. Interspecifically, detection frequencies differed in level and pattern as a function of count period length. The complex nature of detection frequencies is discussed in relation to density and to species-specific activity patterns. Short count periods (3 minutes) are more sensitive to changes in activity levels than long ones. The use of longer periods effectively increases the number of comparable hours for sampling per field day, probably increases the usable length of the field season, and may reduce the effects of observer differences. Analyses of detection frequency data and of species and individual accumulation curves suggest that a point of diminishing returns has been reached well before conducting five 10-minute counts per point. We detect no difference in the effectiveness of same-day and different-day count regimes during our June study period. An increase in count period decreases the number of points that can be surveyed per unit of field time, but increases the total amount of time surveyed. Once between-point time reaches 10 minutes, the count period has little effect on the number of points at which many species are detected per unit of field time. Because data from each has different applications, we recommend that a 10-minute count period with 3- and 5-minute subtotals be used for some monitoring regimes. The selection of the number of repeat counts per point depends on the purpose of the project, but for most monitoring applications three or fewer surveys should be conducted per point per season.

Point counts without distance estimation, i.e., simple tallies of all species and individuals detected during a standard observation period at a specific location, are useful for long-term and comparative monitoring of bird populations (Blondel and others 1981, Robbins and others 1989). The duration, number, and scheduling of individual count periods can be expected to influence this technique's ability to characterize the avifauna at a single point or in a larger sample of points.

The design of a point count monitoring system needs to take into account the tradeoffs between the quality of coverage from intensive sampling at single points and the statistical power of extensive sampling across many points (Verner 1985, 1988). As the amount of time required to move between points is dependent upon topography, access, and the geographic layout of points, the physical character of the terrain will influence the design of optimal sampling regimes.

In this paper we compare the extent of coverage of individual points achieved by using different regimes of count period, number, and scheduling. We then consider the tradeoffs involved between intensive per-point sampling versus extensive among-points sampling as they are influenced by between-point travel time. This paper, however, does not assess quantitatively the influence of these tradeoffs on the statistical power of different monitoring regimes.

Modified point count methods may allow density measurement (Reynolds and others 1980); however, the application of these is difficult and subject to considerable error (Verner 1985). We do not address the issue of density measurement in this paper. Point counts provide an "`audio-visual' density index" (Beals 1960: 158), which can be used most effectively for comparisons of samples from single points or from standardized series of points.

## Methods and Study Areas

### *Terminology*

We attempt to follow the use of terminology summarized in Ralph (1981). In addition, we use *count* for a single bout of surveying at an individual point. A *point* is a single station from which a count is made, and a *site* is a location or tract at which a number of point counts may be made. *Count period* is the duration or length of a single count. As we use it, *coverage* refers to the relative completeness of sampling at a given point, judged against a standard derived from more extensive sampling at that point. A *point count regime* is a specific protocol for the period, number, and schedule of counts at individual points. A *monitoring regime* is a specific protocol for the selection of sites, placement and number of points, and the point count regime employed at those points. *Detection frequency* is the likelihood of observing a species at points where it is known to be present. This differs from "frequency," the proportion of points at which a species is found, which is a function of both presence across points and detectability (Ralph 1981, Verner and Milne 1989). Detection frequencies were calculated as the proportion of counts on which a species was recorded among all counts at points where it was observed at some time during the study.

### *Count Methods*

Counts of all birds seen and heard were made for 10-minute periods with cumulative subtotals recorded at 3- and 6-minute intervals. Birds were identified by primary song, other calls, and sight. All individual birds, except for dependent fledglings, were recorded. Therefore, our data were not limited to territorial or singing males, though these make up the great majority of our records. To reduce the potential for overcounting moving birds, multiple individuals of a species were recorded *only when concurrent observations* clearly established their presence. Field data forms listing most species were used. We follow the nomenclature of the American Ornithologists Union (AOU) Checklist (AOU 1983, table 4). Flyovers and distant birds outside forests (e.g., Northern Bobwhite (*Colinus virginianus*), American Crow (*Corvus brachyrhynchos*), black icterinae except Brown-headed Cowbird (*Molothrus ater*), and House Finch

[1] An abbreviated version of this paper was presented at the Workshop on Monitoring Bird Population Trends by Point Counts, November 6-7, 1991, Beltsville, Maryland.

[2] Professor of Biology and Student Curator of Birds, respectively, Joseph MooreMuseum,Biology Department,Earlham College,Richmond, IN 47374

(*Carpodacus mexicanus*)) were excluded from all our analyses except those producing detection frequencies. We did include American Goldfinch (*Carduelis tristis*), as this species appeared to be a nonbreeding resident in the canopy during our study. To summarize data for a point, we compiled the cumulative total number of species and the highest single counts of individuals for all species.

At each point, five counts were made each morning, one per hour between 0500 and 1000 e.s.t. Sunrise during the study was approximately 0525 e.s.t. Counts were made only on mornings with no rain or leaf drip noise and with winds less than 13 km/h (8 mi/h). This matches the weather restrictions for North American Breeding Bird Surveys (Robbins and others 1986). In practice, winds were less than 6 km/h for more than 90 percent of our counts. Temperatures recorded in the shade 1 m above ground level at the time of our point counts ranged from 16°C-20°C at 0600 and 20°C-26°C at 1000.

### Study Sites

Points were placed more than 50 m inside exterior forest edges and at least 100 m apart. As spacing among points was not sufficient to achieve full independence of data among them, a subset of eight points greater than 150 m apart was used in some of our analyses. Even at this distance, complete independence is not realized for species with far-carrying calls or large home ranges (e.g., Red-bellied Woodpecker (*Melanerpes carolinas*), Pileated Woodpecker (*Drycopus pileatus*), Louisiana Waterthrush (*Seiurus motacilla*)). We believe this lack of total independence among our points does not compromise the specific interpretations we make.

In all, 13 points were surveyed in 3 deciduous woods near Richmond, Wayne County, Indiana. A combined total of 255, 10-minute counts were completed at these points. Robert's Run is a floristically diverse forest (e.g., American beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), flowering dogwood (*Corpus florida*), tulip poplar (*Liriodendron tulipifera*), white ash (*Fraxinus americana*), slippery elm (*Ulmus rubra*), hackberry (*Celtis occidentalis*), black walnut (*Juglans nigra*), eastern red cedar (*Juniperus virginiana*), black cherry (*Prunus serotina*), red oak (*Quercus borealis),* Chinquapin oak (*Q. muhlenbergii*), white oak (*Q. alba*), shagbark hickory (*Carya ovata*), bitternut hickory (*C. cordiformis*), sycamore (*Platanus occidentalis*), cottonwood (*Populus deltoides*)) on dissected terrain with a stream near all points (lat. 39° 45' N., long. 84° 55' W.; 6 points censused on 5 days each, = 150 counts). Canopy heights there ranged from 20 to 25 m. Wildman's Woods is a floristically-mixed forest similar to Robert's Run. It is also on dissected terrain, has a 20- to 25-m canopy, and has a brook near all points (lat. 39° 47' N., long. 84° 58' W.; 3 points censused on 3 days, = 45 counts). Lewis' Woods is a mixed forest with a 25-m canopy on flat land. One point is near a small creek (lat. 39° 56' N., long. 85° 00' W.; 4 points censused on 3 days, 60 counts).

All points were located to avoid significant noise from roads, streams, etc. Robert's Run and Wildman's Woods are parts of extensive wooded complexes of 50+ ha connected to other such complexes by wooded corridors along streams. Lewis' Woods is a 32-ha woodlot. Another 12-ha woods is adjacent across a paved road, but these woods are otherwise well-isolated from other canopied forests by agricultural land.

### Dates

All counts were conducted between June 17 and 30, 1991, with the exception of one set on June 2 at Robert's Run. This period falls well within the breeding season at a time when second clutches and fledgling care are under way for many species. But it is after the peak of song activity for some species, especially permanent residents. April and May 1991 were unusually, warm and wet, and breeding for most species was advanced' a "week' or more compared to most years. Hence, the timing of our counts should yield a mildly conservative measure for typical breeding activity.

### Observers

The two observers were of comparable ability and familiarity with visual; and auditory identification of the breeding birds of the region. We covered separate sets of points and made no attempt to study between-observer effects systematically.

### Point Count Regimes

To evaluate the effectiveness of hypothetical point count regimes, we made the assumption that our level of sampling (15 or more 10-minute counts per point) exceeded a point of diminishing returns and was greatly in excess of the intensity that would be, feasible or desirable for most long-term monitoring projects. To assess the kind of coverage achieved by different point count regimes we selected subsamples from the data for our eight most independent points. We used a total of 150 minutes of sampling over 3 days to establish a "universe" of observations against which to compare the results of subsampling. For this analysis three dates were selected at random from the five dates at each of the Robert's Run points. Differences in numbers of species and of individuals detected by different sampling regimes were tested using one-factor ANOVA.

Three hypothetical sampling intensities at individual points were compared: single counts for each of the three count period durations (i.e., 3-, 6-, and 10-minute samples); *sets of three counts* for each of the durations (totaling 9, 18, and 30 minutes of sampling); and *sets of five counts* for each of the durations (totaling 15, 30, and 50 minutes). Single-count data were selected in a stratified. random fashion from each point (i.e., 3 random samples from: each of the 8 points) to produce a sample size of 24. Three-count sets were compiled in two ways to reflect different sample scheduling: *same-day* compilations of the counts at 0500, 0700, and 0900 and *different-day* compilations using one of these 3 hours from each of the three dates (e.g., 0500 count from the first date, 0700 count from the second date, and 0900 count from the third date; 0700 from the first date, 0900 from the second date, and 0500 from the third date; etc.). Three sets of each type of compilation were produced for each point producing sample sizes of 24. Same-day and different-day sets use the same 9 censuses of each survey point; they differ only in the way they are sorted. Similarly, five-count samples were compiled in two ways: same-day sets from all 5 morning hours and different-day sets from the 3 days using two counts from each of two dates and one from the third (e.g., 0500 and 0800 from one date, 0600 and 0900 from the second date, and 0700 from the third date). Again, sample sizes of 24 were obtained. Finally, a third set ($n$ = 12) of five-count, different-day samples was tabulated for the Robert's Run sites using all five days of data, thereby increasing the number of days sampled in each compilation. This set was compared to the other 5-count compilations from Robert's Run only ($n$ = 12) to evaluate the effect of sampling more days.

## Per Point Coverage
### *Results*

Location and Dates

The cumulative numbers of species and of individuals recorded after 150 minutes of sampling are remarkably similar among our sites (*table 1*). Comparisons of the average number of species and individuals per 10-minute count showed no patterns among dates.

Time of Day

The average numbers of species and individuals recorded declines after 0800 (*table 2*). The decline in species is small and detectable statistically only with 3-minute count periods. The dropoff in the number of individuals recorded is also modest and significant statistically only with 3-minute count periods. In general, the variance for same-hour counts is great compared to between-hour differences in means; even with 3-minute counts, large sample sizes are required to detect these hour-to-hour differences.

Varying Count Period and Number

The coverage obtained from different point count regimes was considered by subsampling from our larger data



**Table 1**--***Cumulative numbers of species and individuals as functions of increasing observation time at 13 points in eastern Indiana deciduous forest. Values are means ± 1 s.e.. RR Roberts Run, WW - Wildman's Woods, LW - Lewis' Woods. n is the number of points. The number of individuals is the sum of the highest counts recorded for each species per point.***

| Site | n | Observer | Observation time (minutes) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 50 | 100 | 150 | 200 | 250 |
| | | | Cumulative Number of Species (*Range*) | | | | |
| RR | 3 | JM | 24.0±2.1 | 27.0±0.6 | 29.0±0.6 | 30.3±0.3 | 31.0 ± 0.0 |
| | | | (20-27) | (26-28) | (28-30) | (30-31) | (31) |
| RR | 3 | WB | 24.7±0.7 | 26.7±0.9 | 28.3±0.7 | 30.0±0.6 | 30.7±0.3 |
| | | | (24-26) | (25-28) | (27-29) | (29-30) | (30-31) |
| WW | 3 | JM | 21.3±0.3 | 25.3±0.3 | 28.0±0.6 | | |
| | | | (21-22) | (25-26) | (27-29) | | |
| LW | 4 | WB | 20.0±0.7 | 23.8±0.9 | 26.3±1.1 | | |
| | | | (19-22) | (22-26) | (24-29) | | |
| | | | Cumulative Number of Individuals (*Range*) | | | | |
| RR | 3 | JM | 37.0±3.1 | 47.0±1.5 | 51.7±1.2 | 55.3±2.0 | 57.7±0.9 |
| | | | (31-41) | (45-50) | (50-54) | (52-59) | (56-59) |
| RR | 3 | WB | 37.7±1.3 | 44.3±3.0 | 48.0±2.1 | 52.3±3.3 | 54.7±3.4 |
| | | | (35-39) | (40-50) | (45-52) | (46-57) | (48-59) |
| WW | 3 | JM | 31.3±0.9 | 40.3±2.0 | 46.3±0.3 | | |
| | | | (30-33) | (37-44) | (46-47) | | |
| LW | 4 | WB | 33.0±0.7 | 40.0±1.5 | 44.0±1.2 | | |
| | | | (31-34) | (37-43) | (42-47) | | |

**Table 2**--***Number of species and individuals (mean + s.e.) recorded by time of day with different count period durations. Sample size equals 51 for all.***

| Count period (minutes) | Hour beginning (e.s.t.) | | | | |
|---|---|---|---|---|---|
| | 0500 | 0600 | 0700 | 0800 | 0900 |
| | ---------------------*Number of Species*--------------------------------------------- | | | | |
| 3 | 10.1±0.4 | 10.0±0.3 | 9.9±0.4 | 9.1±0.4 | 8.5±0.4[a] |
| 6 | 11.9±0.4 | 12.0±0.3 | 12.1±0.4 | 11.3±0.4 | 11.2±0.4 |
| 10 | 13.4±0.4 | 13.9±0.4 | 13.6±0.4 | 13.3±0.4 | 12.9±0.4 |
| | -----------------*Number of Individuals*------------------------------------------- | | | | |
| 3 | 13.2±0.5 | 12.9±0.5 | 12.5±0.5 | 11.4±0.5 | 10.7±0.6[a] |
| 6 | 16.0±0.5 | 15.9±0.5 | 15.8±0.6 | 14.6±0.6 | 14.4±0.6 |
| 10 | 18.5±0.5 | 19.0±0.6 | 18.3±0.6 | 17.6±0.6 | 16.9±0.7 |

[a] Significant differences among hours only for 3-minute count periods (ANOVA): $F$ = 3.5, $P$ = 0.008 (species); $F$ = 4.1, $P$ = 0.003 (individuals). For 10-minute periods $F$ = 0.89, $P$ = 0.47 (species) and $F$ = 1.8, $P$ = 0.14 (individuals).

set using hypothetically varied count durations, numbers, and schedules. The total number of species and the total number of individuals increases when the count period is increased from 3 to 6 minutes and from 6 to 10 minutes ($P < 0.001$ for all comparisons, *table 3*). The species-effort relationship for point counts is asymptotic, but even after 150 minutes per point new species and individuals continue to be recorded at low rates (*table 1*). It is the nature of these data that no matter what amount of time has been sampled, the relationship appears to have neared its asymptote.

In our subsampled regimes, the numbers of species and individuals increase significantly as the number of counts increases from one to three and from three to five for each count period duration ($P < 0.001$ for all comparisons (*table 3*)). Single, 10-minute counts yield averages of only about 48 percent of the total species and 37 percent of the individuals recorded in the 150-minute pool from which they were drawn (*table 1*). Coverage increases to about 72 percent of species and 61 percent of individuals for three 10-minute counts and 83 percent of species and 73 percent of individuals for five 10-minute counts.

The influence of the count period on coverage is substantial but declines as the total number of counts increases. The increase from a 3- to 10-minute count period yields about 43 percent more species and 49 percent more individuals (*table 3*). When sets of three counts are made, using a 10-minute rather than a 3-minute count period, increases of 30 percent and 39 percent are produced, and with 5 counts the increases are 24 percent and 34 percent.

The influence of the number of counts on coverage is also substantial but declines rapidly as the number of counts increases. The move from a single count to three counts produces, depending on the count period duration, 51-66 percent more species and 65-76 percent more individuals, but the move from 3 to 5 counts yields increases of only 15-21 percent and 20-25 percent (*table 3*).

By holding the total observation time constant, the effect of changing the number of counts is demonstrated in the following comparisons. Three, 3-minute, same-day counts (9 minutes total) detect more species ($F = 8.6$, $P = 0$ .005) and individuals ($F = 7.6$, $P = 0.008$) than single 10-minute counts (*table 3*). Thirty-minute samples can be obtained by three 10-minute counts and by five 6-minute counts. No significant differences in results are found between these regimes (e.g., for 3 same-day, 10-minute counts versus 5 same-day, 6-minute counts: species, $F = 1.8$, $P = 0.18$; individuals, $F = 1.5$, $P = 0.22$; etc.).

Varying Schedule

We find that, within our late June sampling season, the scheduling of counts among days has no effect on coverage. Comparisons of single-day counts with different-day count regimes of equal sampling time show no significant differences in the average numbers of species or individuals detected (*table 3*). These comparisons were made at 3-, 6-, and 10-minute count periods for the following pairs of regimes: 3 same-day versus 3 different-days (all sites); 5 same-day versus



**Table 3**-***Average cumulative numbers of species and the average maximum numbers of individuals detected at eight forest points using different regimes of point count duration, number, and schedule. n is the number of samples per regime. Values are means + 1 s.e.***

| Sampling regime (Number of counts, schedule) | Count period duration (minutes) 3 | 6 | 10 | *n* |
|---|---|---|---|---|
| | *Number of Species* | | | |
| **All sites:** | | | | |
| l, single count | 9.3+0.4 | 11.3+0.4 | 13.3+0.4 | 24 |
| 3, same day | 15.2+0.5 | 17.5+0.6 | 19.6+0.6 | 24 |
| 3, different days | 15.5+0.5 | 18.2+0.6 | 20.5+0.5 | 24 |
| 5, same day | 18.4+0.5 | 20.6+0.5 | 22.6+0.5 | 24 |
| 5, three different days | 18.8+0.6 | 21.8+0.6 | 23.6+0.5 | 24 |
| **Robert's Run only:** | | | | |
| 5, same day | 19.3+0.9 | 22.0+0.9 | 23.8+0.7 | 12 |
| 5, three different days | 19.4+0.8 | 23.3+0.7 | 24.5+0.5 | 12 |
| 5, five different days | 20.0+0.6 | 22.1+0.6 | 24.3+0.7 | 12 |
| | *Number of Individuals* | | | |
| **All sites:** | | | | |
| 1, single count | 11.9+0.7 | 14.8+0.6 | 17.7+0.7 | 24 |
| 3, same day | 20.6+0.8 | 24.8+0.9 | 28.7+1.0 | 24 |
| 3, different days | 21.3+0.9 | 25.5+0.9 | 29.8+0.9 | 24 |
| 5, same day | 25.9+0.8 | 30.3+0.9 | 34.3+0.9 | 24 |
| 5, three different days | 26.6+0.9 | 31.6+0.8 | 35.8+0.9 | 24 |
| **Robert's Run only:** | | | | |
| 5, same day | 26.7+1.5 | 31,7+1.4 | 35.6+ 1.3 | 12 |
| 5, three different days | 27.5+1.4 | 32.9+1.2 | 36.8+1.2 | 12 |
| 5, five different days | 27.8+1.5 | 32.6+1.4 | 37.1+1.4 | 12 |

5 on 3 different-days (all sites); and 5 same-day versus 5 different-days (Robert's Run sites only).

***Discussion of Point Count Coverage***

Count Period and Time of Day

The numbers of species and individuals recorded on point counts appear to decline in midmorning, but only for 3-minute counts are these declines statistically demonstrable, and then only with large sample sizes (*table 2*). These modest declines in counts in the 0800 and 0900 hours may result from reduced activity levels or observer fatigue. Whatever the cause, data from longer count periods are less affected than those from shorter counts. Ten-minute counts allow more time either for relatively inactive birds to move or give calls (Robbins 1981) or for weary observers to register the bird's presence. The lack of significant differences in numbers of species or individuals for 6- and 10-minute count periods during the first 4 hours of daylight is similar to the results in California habitats (Verner and Ritter 1986). They used only 8- and 10-minute point counts and generally considered only the first 4 hours of daylight. Other point count studies detecting hour-to-hour differences during the morning have been based on large sample sizes and short count periods (Robbins 1981).

For practical purposes, the use of longer count periods extends usable field time. When 6- or 10-minute count periods are used, the 0900 hour is not significantly different from earlier hours for point count productivity. We agree with Verner and Ritter (1986) that the benefit of using more morning hours for surveys outweighs the potential negative effects from changes in activity before 1000. We did not anticipate this result, and we did not sample after 1000. Therefore, we cannot speak to the midday performance of different count periods. Just as longer count periods compensate for declining activity later in the morning, they should serve to extend the usable field season when song intensity begins to diminish at the end of the breeding season.

Comparison of Monitoring Regimes

An approach to estimating an effective level of sampling per point is to consider the sampling effort needed to reach a point of diminishing returns for the number of species and individuals detected. Substantially more species and individuals are detected by increasing count period length and by increasing the number of counts made (*tables 2* and *3*). Increasing the number of counts from three to five produces significant, but modest improvement in coverage in view of the effort involved. This approach suggests that a point of diminishing return has been reached before five 10-minute samples per site have been conducted.

The lack of significant differences between same-day sampling and different-day sampling indicates that where sampling across days is logistically inefficient, same-day coverage of equal duration is a suitable alternative.

**Detection Frequencies: Species Comparisons**

***Results***

The tendency toward a modest decline in numbers of individuals through the morning is not demonstrated as a significant pattern in the detection frequency of any single species (*table 2*). However, the American Goldfinch is detected more frequently after the first hour of daylight ($X^2$ = 14.2, df = 4, $P < 0.01$, 10-minute count period). Brown-headed Cowbirds had a distinct 0700 peak for 3-minute count periods ($X^2 = 12.1$, $P < 0.025$), a pattern that is not significant in 10-minute count data.

Species detection frequencies ($f_{sp}$) show striking differences among species (*table 4*). For purposes of comparison, we group species into categories based on the predicted number of 10-minute counts it would take to reach a 90 percent likelyhood of detecting them *if the species is present at a point* (i.e., $(1 - (1 - f_{sp})^c)$ estimates the likelihood of detecting the species after c counts at a point where it occurs).

The pattern of detection frequencies as a function of the count period also differs among species (*table 4*). Some species are detected at high frequencies during 3-minute counts, and the likelihood of their detection is not much increased in longer counts (e.g., Eastern Wood-Pewee (*Conotopus virens*), Acadian Flycatcher (*Empidonax virescens*), Wood Thrush (*Hylocichla mustelina*), Red-eyed Vireo (*Vireo olivaceus*), Kentucky Warbler (*Oporornis formosus*), and Indigo Bunting (*Passerina cyanea*)); others show relatively large increases in detection as the count period increases (e.g., Ruby-throated Hummingbird (*Archilocus colubris*), Red-bellied Woodpecker, Downy Woodpecker (*Picoides pubescens*), American Crow, White-breasted Nuthatch (*Sitta carolinensis*), Brown-headed Cowbird, and American Goldfinch). Few species demonstrate detection frequencies directly proportional to the count period length (e.g., for 3-, 6-, and 10-minute periods: Great Blue Heron (*Ardea herodias*) - 0.03, 0.07, 0.10, $n$ = 20; Chimney Swift (*Chaetura pelagica*) - 0.01, 0.04, 0.07, $n$ = 18; and Ruby-throated Hummingbird (*table 4*)).

***Discussion of Detection Frequencies***

The concept of "frequency," the number of points at which a species is detected divided by the total number of points sampled, can be parsed into its components (Ralph 1981, Verner and Milne 1989). It is a function of both the proportion of points sampled at which a species occurs (i.e., the frequency of occurrence) and the proportion of counts on which the species is recorded where it occurs (i.e., the species' detection frequency). In turn, a species' detection frequency is the product of both the detection frequency of a single individual and the number of individuals present at a given point.

Interspecifically, detection frequencies vary greatly. Species that vocalize continuously or are present at higher densities, as suggested by a higher maximum number of individuals recorded per point (e.g., Acadian Flycatcher, Wood Thrush, Red-eyed Vireo, and Northern Cardinal (*Cardinalis cardinalis*)), are readily recorded within 3 minutes and show little change in detection frequency as count period increases from 3 to 10 minutes (*table 4*). For these species at least one individual is so likely to be active in the first 3 minutes of observation that the species is rarely missed then.

We would anticipate that if such a species' abundance declined, its pattern of detection would begin to resemble that of currently less dense but similarly vocal species like

**Table 4**-*Detection frequencies for species during 3-, 6-, and 10-minute count periods. Frequencies are the proportions of counts on which the species was recorded among all counts at points where it was observed at some time during the study (no.). Mean number of individuals is the average of maximum counts of individuals for all points where the species was found. If frequency ≥0.55, then three or fewer counts are needed to yield ≥90 percent probability of detecting the species. If >0.37 but ≤0.54, four or five counts are needed. If ≥0.21 but ≤ 0.36, 6 to 10 counts are needed If <0.21, more than 10 counts are needed.*

| Species | Frequency Count Period (minutes) 3 | 6 | 10 | Sites | Points | Counts | Mean number of individuals |
|---|---|---|---|---|---|---|---|
| | | | | ----------no.---------- | | | |
| Frequency > 0.55: | | | | | | | |
| Red-bellied Woodpecker | 0.45 | 0.51 | 0.70 | 3 | 13 | 255 | 1.8 |
| Eastern Wood-Pewee | 0.62 | 0.69 | 0.73 | 3 | 13 | 255 | 1.6 |
| Acadian Flycatcher | 0.75 | 0.81 | 0.85 | 3 | 13 | 255 | 2.4 |
| Tufted Titmouse | 0.58 | 0.65 | 0.73 | 3 | 13 | 255 | 2.6 |
| House Wren | 0.53 | 0.58 | 0.60 | 2 | 5 | 85 | 1.8 |
| Blue-gray Gnatcatcher | 0.38 | 0.53 | 0.57 | 3 | 11 | 225 | 1.6 |
| Wood Thrush | 0.68 | 0.74 | 0.77 | 3 | 13 | 255 | 2.5 |
| Red-eyed Vireo | 0.73 | 0.80 | 0.83 | 3 | 13 | 255 | 2.3 |
| Cerulean Warbler | 0.58 | 0.67 | 0.73 | 2 | 8 | 180 | 2.1 |
| Northern Cardinal | 0.71 | 0.86 | 0.90 | 3 | 13 | 255 | 2.8 |
| Indigo Bunting | 0.49 | 0.55 | 0.60 | 3 | 13 | 255 | 2.0 |
| Brown-headed Cowbird | 0.37 | 0.53 | 0.65 | 3 | 13 | 255 | 3.6 |
| Frequency = 0.37 - 0.54: | | | | | | | |
| Northern Bobwhite | 0.40 | 0.45 | 0.52 | 1 | 4 | 60 | 1.5 |
| American Crow | 0.21 | 0.31 | 0.40 | 3 | 13 | 255 | 2.5 |
| Carolina Chickadee | 0.33 | 0.40 | 0.48 | 3 | 13 | 255 | 2.5 |
| White-breasted Nuthatch | 0.20 | 0.30 | 0.37 | 3 | 13 | 255 | 1.4 |
| Carolina Wren | 0.31 | 0.46 | 0.50 | 2 | 9 | 195 | 2.1 |
| Ovenbird | 0.29 | 0.36 | 0.39 | 2 | 4 | 70 | 1.3 |
| Kentucky Warbler | 0.31 | 0.36 | 0.41 | 2 | 9 | 195 | 1.9 |
| Scarlet Tanager | 0.38 | 0.50 | 0.53 | 3 | 13 | 255 | 1.5 |
| American Goldfinch | 0.29 | 0.40 | 0.52 | 3 | 13 | 255 | 2.2 |
| Frequency = 0.21 – 0.36: | | | | | | | |
| Yellow-billed Cuckoo | 0.14 | 0.18 | 0.26 | 3 | 12 | 240 | 1.5 |
| Downey Woodpecker | 0.15 | 0.23 | 0.29 | 3 | 13 | 255 | 1.3 |
| Blue Jay | 0.16 | 0.21 | 0.25 | 3 | 13 | 255 | 1.7 |
| Yellow-throated Warbler | 0.16 | 0.24 | 0.33 | 1 | 6 | 150 | 1.0 |
| Louisiana Waterthrush | 0.18 | 0.26 | 0.34 | 2 | 9 | 195 | 1.2 |
| Frequency < 0.21: | | | | | | | |
| Wild Turkey | 0.12 | 0.12 | 0.12 | 1 | 1 | 25 | 1.0 |
| Black-billed Cuckoo | 0.07 | 0.10 | 0.13 | 2 | 2 | 40 | 1.0 |
| Great Horned Owl | 0.06 | 0.06 | 0.06 | 1 | 1 | 15 | 1.0 |
| Ruby-throated Hummingbird | 0.04 | 0.10 | 0.16 | 3 | 11 | 225 | 1.3 |
| Hairy Woodpecker | 0.09 | 0.13 | 0.19 | 3 | 10 | 190 | 1.0 |
| Northern Flicker | 0.05 | 0.09 | 0.14 | 3 | 10 | 200 | 1.0 |
| Pileated Woodpecker | 0.02 | 0.05 | 0.06 | 3 | 9 | 170 | 1.1 |
| Great Crested Flycatcher | 0.07 | 0.10 | 0.16 | 3 | 11 | 225 | 1.3 |
| Yellow-throated Vireo | 0.08 | 0.11 | 0.16 | 2 | 8 | 180 | 1.0 |
| Hooded Warbler | 0.11 | 0.13 | 0.13 | 1 | 3 | 45 | 1.0 |

The following additional species with frequencies < 0.21 were recorded as fly-overs, birds heard from outside forest habitat, or as probable nonbreeding vagrants: Great Blue Heron; Killdeer, Mourning Dove; Chimney Swift; Belted Kingfisher; Purple Martin; Eastern Kingbird; Eastern Bluebird; American Robin; Gray Catbird; Brown Thrasher; European Starling; Black-throated Green Warbler; American Redstart; Yellow-breasted Chat; Rose-breasted Grosbeak; Field Sparrow; Red-winged Blackbird; Common Grackle; Northern Oriole; and House Finch.

Cerulean Warbler (*Dendroica cerulea*), Blue-gray Gnatcatcher (*Polioptila caerulea*), Ovenbird (*Seirus aurocapillus*), Scarlet Tanager (*Piranga olivacea*), and Yellow-throated Warbler (*Dendroica dominica*). Species with large territories are not likely to be recorded frequently at any given point (e.g., Pileated Woodpecker, and Louisiana Waterthrush).

If the likelihood that a species will be detected at a given point is a function of the number of individuals present, an interesting relationship exists between actual density and the detection frequencies derived from different count periods. As density at a given point declines, the change in detection frequencies for short count periods more nearly reflects the actual decline than frequencies based on data from longer periods (*table 5*). The species detection frequency as a function of the number of birds present is hypothesized to be: $f_{sp} = (1 - (1 - f_{in})^n)$, where $f_{in}$ is the frequency of detection of single individuals and *n* is the number of individuals present. This model assumes no facilitation or inhibition of activity among birds within earshot of the observer. If this model applies, the use of longer count periods underestimates actual declines (or increases) in the number of individuals per point to a greater extent than the use of shorter periods (*table 5*).

Density alone does not account for all differences in detection patterns. Obviously, changes in calling rates through the season will influence detection frequencies. We suspect that we have low estimates of frequency for some resident and early migrant species because our study was late, after their activity peaked (e.g., Downy Woodpecker, Hairy Woodpecker (*Picoides villosus*), Northern Flicker (*Colaptes auratus*), Carolina Chickadee (*Parus carolinensis*), Yellow-throated Warbler, and Louisiana Waterthrush). Also species specific singing patterns influence the likelihood of detection as a function of the count period. Species that sing more or less continuously in bouts of considerable duration are highly likely to be detected in the first 3 minutes (e.g., Eastern Wood-Pewee, House Wren (*Troglodytes troglodytes*), Red-eyed Vireo, Cerulean Warbler, and Indigo Bunting). Their frequencies for longer count periods will not climb rapidly. Others that give single calls or short bouts at greater intervals are more apt to be missed during the first 3 minutes and recorded in proportion to the time spent observing (e.g., Yellow-billed Cuckoo (*Coccyzus americanus*), Red-bellied Woodpecker, Hairy Woodpecker, Great Crested Flycatcher (*Myiarchus crinitus*), American Crow, White-breasted Nuthatch, and Brown-headed Cowbird). Species that are detected in rare, brief events are apt to be recorded nearly at random and in proportion to the time spent counting (e.g., Ruby-throated Hummingbirds and other "fly-bys" like herons, black icterinae, etc.). For recording rarely detected species, the benefits of longer count periods are greater than for common species (*table 4*). These differences in detectability among species indicate optimal monitoring regimes may differ depending on the species studied. At the least, larger amounts of time must be spent to establish the presence or absence of some species.

Unmated males of some species sing more actively than mated individuals (Gibbs 1988, Hayes and others 1985). This poses a troublesome bias if point count detections are used to assess habitat optima. The specter of detection rates increasing as a population declines is raised by these observations. 'Presence/absence' data from longer count periods will be less biased by differences in song activity levels among residents.



**Table 5--*Relationships among species detection frequencies, count period, and number of individuals present at a point.***

1. Hypothetical species detection frequencies as functions of the number of individuals (*n*) and count period. The random model sets individual detection frequencies at a moderate magnitude and in proportion to count period length. Yellow-throated Warbler model uses frequencies for a species thought to have been represented by only one individual per point.
$f_{in}$ is the detection frequency for a single individual. $f_{sp}$ is the species detection frequency calculated as: $(1 - (1 - f_{in})^n)$, where *n* is the number of individuals present.

| | | Count Period (minutes) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Random model | | | Yellow-throated Warbler | | |
| Frequency | *n* | 3 | 6 | 10 | 3 | 6 | 10 |
| $f_{in}$ = | | 0.15 | 0.30 | 0.50 | 0.16 | 0.24 | 0.33 |
| $f_{sp}$ = | 1 | 0.15 | 0.30 | 0.50 | 0.16 | 0.24 | 0.33 |
| $f_{sp}$ = | 2 | 0.28 | 0.51 | 0.75 | 0.29 | 0.42 | 0.55 |
| $f_{sp}$ = | 3 | 0.39 | 0.66 | 0.87 | 0.41 | 0.56 | 0.70 |
| $f_{sp}$ = | 4 | 0.48 | 0.76 | 0.94 | 0.50 | 0.67 | 0.80 |

2. The predicted percent decline in species detection rates as a function of count period given hypothetical declines in the number of individuals present. The percent decline in species detection frequency is ratio of ($f_{sp}$ before decline minus $f_{sp}$ after decline) to ($f_{sp}$ before decline).

| Hypothetical decline in number of individuals | | Percent decline in species detection frequency | | | | | |
|---|---|---|---|---|---|---|---|
| | | Count Period (minutes) | | | | | |
| | | Random model | | | Yellow-throated Warbler | | |
| Numbers | Percent | 3 | 6 | 10 | 3 | 6 | 10 |
| 2 →1 | 50 | 46 | 41 | 33 | 45 | 43 | 40 |
| 3 →1 | 67 | 62 | 55 | 43 | 61 | 57 | 53 |
| 4 →1 | 75 | 69 | 61 | 47 | 68 | 64 | 59 |

A further factor influencing detection rates across species and across count period lengths is observer bias (Verner 1985, Verner and Milne 1989). Unconsciously or consciously, we tended to start our counts by listening for specific species (in our cases usually parulinae) and change to other species later in the count period. One of us recognizes that he filters out crows whenever anything interesting is calling. Rare species, because of their intrinsic interest, are less apt to be missed or go unrecorded than common species. We believe that the prompting offered by a prepared data sheet with a species list reduced our likelihood of overlooking some species. In general, longer count periods are likely to reduce the effects of observer biases stemming from differences in alertness and, perhaps, some forms of acuity (e.g., stimulus filtering or saturation).

Our frequency values suggest that the majority of breeding passerine species are detected by five 10-minute samples (*table 4*). Because our study was conducted late in the season of some species' activities, we believe this may be a modest overestimate of the sampling effort required for our sites.

## Design of Monitoring Regimes

### *Tradeoffs Between Count Period and Travel Time*

Thus far we have considered sampling effectiveness as it relates to the coverage of individual points. Ultimately, statistical power in monitoring population trends depends on surveying large numbers of points (Verner 1985, 1988). Trends are detected as changes in frequencies of occurrence across points and the statistics of larger samples are less likely to be influenced by stochastic changes in habitat or observation variability at a few points.

The number of points covered per unit time is a function of count period and between-point travel intervals; the quality of per-count coverage depends on the count period. Where average travel time (i.e., "noncounting time") among independent points is great, the number of points that can be covered per unit of field time is limited (Verner 1988). Travel times are considerable in cases where lack of roads or trails makes access difficult as when wilderness areas or scattered Midwestern woodlots are to be monitored. It is important to consider the tradeoffs between count period duration and the number of counts in designing effective monitoring regimes, especially under these conditions.

For any given travel time, an increase in count period decreases the number of counts per hour, but increases the total time spent counting. For example, when travel time is 2 minutes, a change in count period from 3 to 10 minutes gives a 58 percent decrease in number of points and a 39 percent increase in survey time (*table 6*). At 10-minute travel intervals, the change in period reduces the count number by 35 percent and increases the time surveyed by 114 percent.

The tradeoffs of selecting different count periods can be illustrated by comparing the total number of individuals recorded per hour under different regimes (Droege and Ralph, personal communication). Using our results, when travel time between points is short, as if it were the 2-minute period used for roadside surveys (Robbins and others 1986), 3-minute counts produce about 60 percent more individuals per hour of field time than 10-minute counts (*table 6*). This difference disappears under conditions where between-point travel time approaches 10 minutes. The number of species-point records (i.e., the number of species per point summed over all points) shows the same pattern.

This approach can also be used to compare the efficiency of different count periods at detecting individual species (*table 7*). For some common and vocally active species like Acadian Flycatcher, Red-eyed Vireo, Wood Thrush, and Cerulean Warbler, shorter count periods produce a greater number of point records per hour. However, as travel intervals increase to 10 minutes, this relative advantage of shorter counts diminishes. For species with detection frequencies that



***Table 6-Sampling effects of the tradeoff between count period duration and between point travel time.***

1. Effects on the number of counts and number of minutes surveyed per hour.

| | Count period duration (minutes) | | | | | |
|---|---|---|---|---|---|---|
| | 3 | 6 | 10 | 3 | 6 | 10 |
| Travel time (minutes) | Counts/hour | | | Minutes/hour | | |
| 2 | 12.0 | 7.5 | 5.0 | 36 | 45 | 50 |
| 5 | 7.5 | 5.4 | 4.0 | 23 | 33 | 40 |
| 10 | 4.6 | 3.8 | 3.0 | 14 | 23 | 30 |

2. Effects on the number of individuals recorded per hour and the number of species-points per hour. Species-points are the sum of the number of species per point for all points covered. Mean is the mean number of individuals and species per point, carried from the data in *table 3*.

| | | Count period duration (minutes) | | | | | |
|---|---|---|---|---|---|---|---|
| | | 3 | 6 | 10 | 3 | 6 | 10 |
| Travel time (minutes) | | Individuals/hour | | | Species-points/hour | | |
| | Mean = | 11.9 | 14.8 | 17.7 | 9.3 | 11.3 | 13.3 |
| 2 | | 143 | 111 | 89 | 108 | 85 | 67 |
| 5 | | 89 | 80 | 71 | 70 | 61 | 53 |
| 10 | | 55 | 56 | 53 | 43 | 43 | 40 |

**Table 7**—***Effects of the tradeoffs between count period duration and between point travel time on the number of points at which selected species will be recorded per hour. The values are based on the frequency of a species' detection ($f_{sp}$), the proportion of counts in which it was detected* (table 4) *at points where it occurred. The values therefore represent a model situation in which the species is present at all points. Acadian Flycatcher's pattern is approximately the same as those of Red-eyed Vireo and Wood Thrush. Yellow-throated Warbler's pattern is similar to that of the Louisiana Waterthrush.***

| Travel time (minutes) | | *Count period duration (minutes)* | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 3 | 6 | 10 | 3 | 6 | 10 | 3 | 6 | 10 |
| | | *Number of points per hour* | | | | | | | | |
| | | Acadian Flycatcher | | | Cerulean Warbler | | | Red-bellied Woodpecker | | |
| | $f_{sp}$ = | 0.75 | 0.81 | 0.85 | 0.58 | 0.67 | 0.73 | 0.45 | 0.51 | 0.70 |
| 2 | | 9.0 | 6.1 | 4.3 | 7.0 | 5.0 | 3.7 | 5.4 | 3.8 | 3.5 |
| 5 | | 5.6 | 4.4 | 3.4 | 4.4 | 3.6 | 2.9 | 3.4 | 2.8 | 2.4 |
| 10 | | 3.5 | 3.0 | 2.6 | 2.7 | 2.5 | 2.2 | 2.1 | 1.9 | 2.1 |
| | | Brown-headed Cowbird | | | Scarlet Tanager | | | Kentucky Warbler | | |
| | $f_{sp}$ = | 0.37 | 0.53 | 0.65 | 0.38 | 0.50 | 0.53 | 0.31 | 0.36 | 0.41 |
| 2 | | 4.4 | 4.0 | 3.3 | 4.6 | 3.8 | 2.7 | 3.7 | 2.7 | 2.1 |
| 5 | | 2.8 | 2.9 | 2.6 | 2.9 | 2.7 | 2.1 | 2.3 | 1.9 | 1.6 |
| 10 | | 1.7 | 2.0 | 2.0 | 1.7 | 1.9 | 1.6 | 1.4 | 1.4 | 1.2 |
| | | Yellow-throated Warbler | | | R.-thr. Hummingbird | | | | | |
| | $f_{sp}$ = | 0.16 | 0.24 | 0.33 | 0.04 | 0.10 | 0.16 | | | |
| 2 | | 2.0 | 1.8 | 1.7 | 0.5 | 0.8 | 0.8 | | | |
| 5 | | 1.2 | 1.3 | 1.3 | 0.3 | 0.5 | 0.6 | | | |
| 10 | | 0.7 | 0.9 | 1.0 | 0.2 | 0.4 | 0.5 | | | |

increase substantially with count period like Red-bellied Woodpecker, Brown-headed Cowbird, Scarlet Tanager, Kentucky Warbler, Yellow-throated Warbler, Louisiana Waterthrush, and Ruby-throated Hummingbird, shorter count periods produce more station records only when travel intervals are short. Little is gained by using shorter count periods when between-point travel times approach or exceed 10 minutes, especially for relatively uncommon species, which are apt to be the targets of many monitoring programs.

### *Layout of Points*

When selecting a monitoring regime, optimization can be approached by adjusting two variables: between-point travel interval and count period (Verner 1988). Travel time is less readily adjusted as it is strongly constrained by the physical environment. Nevertheless, travel time depends on decisions about the layout of points. It can be reduced by placing points: (1) close together; (2) along topographic contours; or (3) along trails to improve ease of movement. It can be shortened greatly if points are placed along roads and a vehicle is used. In each case, these decisions may compromise statistical assumptions about independence of points or representativeness of the sample.

The primary goal of most long-term monitoring is to detect trends in bird populations. To do this using a series of repeated point counts, it is necessary to make the assumption that changes in our counts over time are representative of changes in populations on a larger regional scale. We assume that no changes in habitat quality will occur among our sample points that are unrepresentative of changes in habitats in general. Either we place our points representatively (probably involving random placement) or we apportion them more or less equally among defined habitat types and then must separately monitor changes in the frequency of these habitats over time on the regional level.

The use of trails or roadsides for monitoring is based on the assumption that these points will continue to sample habitats representatively over the next decades, and that disturbance regimes (Denslow 1980) and patch dynamics (Pickett 1980, Pickett and Thompson 1978) will be no different along them than elsewhere. Among other aspects, this assumes that current trails are not laid out unrepresentatively relative to successional states of habitats. This is an assumption that cannot be made in those National Forests where trails are more apt to be on ridges or along streamsides where historic land use is likely to have been more intense than on slopes.

The papers at this workshop that compare roadside to off-road point counts find modest differences between selected points (Hutto and Hejl, in these Proceedings, Keller and Fuller, in this volume, Ralph and others, in this volume), yet they do not establish equivalent susceptibility of these areas to disturbance through time (e.g., fires, forest harvest, windfalls, and rights-of-way maintenance).

Several papers in this symposium mention the importance of adequately sampling habitat types as units. There are compelling management reasons to tie population data to habitat classifications. However, the definitions of forest types or stands may pose a variety of difficulties for long-term monitoring. If any of these are successional habitats, their character will change over time. Relatively uncommon habitats may be oversampled now compared to later, when succession has removed them from sampled points, but disturbance and succession have not replaced them proportionally at other points. Likewise, the layout of points should not avoid existing disturbed habitats (e.g., treefall gaps, burns, etc.) as this will produce a nonrepresentative sampling now compared to later when future disturbances will have affected some of the points we set up now.

This all argues for random placement of points--or careful attention must be paid to comparing the dynamics of habitats at count points to those at regionally-representative points so that point count data can be converted to assess actual population trends. Arguing against random placement is the loss of sample size that results from increased travel time between points and the loss of clear ties to current habitat classification schemes as a component of management decision making. A compromise is required in setting up a point count monitoring program. The decisions made in setting up a system should be clearly documented so that future interpretations of trends in the data can be made more knowledgeably.

### *Pros and Cons of Different Count Period Durations*

Compared to longer count periods (e.g., 10 minutes), the use of shorter count periods (e.g., 3 minutes) has advantages, such as: (1) more counts can be conducted per unit of field time; (2) 3-minute counts are compatible with the existing large Breeding Bird Survey (BBS) data base; and (3) changes in detection frequencies will more closely measure changes in abundance at individual points (longer periods will underestimate changes in abundance). The use of short count periods also has disadvantages, such as: (1) less time will be spent censusing per unit of field time; (2) greater sensitivity to changes in activity levels during the day (and probably the season) thereby "shortening" the day (they may also be more sensitive to observer differences); (3) greater sensitivity to differences in activity levels among species and individuals; and (4) lower effectiveness at sampling less abundant or less conspicuous species on a per-point basis.

Increases in between-point travel time affect the relative strengths of these advantages and disadvantages of designs with shorter count periods. As travel interval increases, the advantage of more points per unit of field time decreases and the disadvantage of less time counting per unit of field time intensifies. At travel intervals of approximately 10 minutes, the advantages of shorter count periods are expressed only in the more common (dense and easily detected) species.

### *Recommendations*

Because the advantages of increasing sample sizes are great (Verner 1985, 1988), shorter count periods (i.e., 3 or 5 minutes) should be used whenever between-point travel times are short (approximately 2 to 5 minutes). This assumes that the layout of points to achieve reduced between-point time does not compromise the assumptions necessary for statistical analysis or the representativeness of the sample points.

Multiple counts per point during a season yield improved coverage, thereby improving the data for presence or absence determinations such as those used in habitat association analyses. A point of diminished returns has certainly been reached with five 10-minute counts per point. However, repeated counts substantially reduce the number of points that can be canvassed per unit effort. Based on our results, more than three counts per season at a point seems unwarranted for population monitoring purposes.

Some monitoring projects will have special reasons to be designed with long travel times among points. For example, given the possible alternative patterns of habitat selection by declining populations (Askins and others 1990, Robbins and others 1989, Wilcove and Terborgh 1984), monitoring forests of differing vegetation, sizes, and geographic relationships is crucial. When point counts are used to monitor patterns like these of habitat selection in fragmented landscapes, large numbers of suitable sites with multiple points per site may not be available or feasible and travel times among sites will be great. Increased per-point sampling intensity will be at a premium. Longer count periods, and perhaps multiple counts per point, will yield better correlations between species presence and habitat states: there will be fewer events of missed detection at points with suitable and occupied habitats. A similar situation would exist when monitoring roadless or pathless wilderness areas.

In situations such as these, where access to points will involve relatively long travel times, and therefore the relative advantages of short versus long periods diminish, we would recommend the use of longer count periods. A mixed method in which 10-minute count periods are subtallied at the 3- and 5-minute intervals would have many benefits, such as: (1) comparability with BBS (3 minutes) and with the standard recommended by this workshop (5 minutes); (2) improved coverage per point (10 minutes) for better habitat association analysis, especially for less frequently detected species; (3) increased amount of time per day with comparable sampling (10 minutes) and, perhaps, increased length of season with comparable sampling; (4) abatement of variance due to breeding status effects on activity levels (10 minutes); (5) perhaps abatement of variance because of some observer differences (10 minutes); and (6) ability to more directly estimate changes in populations from changes in detection frequencies (3 minutes).

In many cases such as monitoring fragments or pockets of rare habitats, the geographic layout of study areas requires large amounts of travel time among sites and relatively less among points within sites. Only one or a few independent monitoring points can be placed in each site. In these situations, multiple same-day counts within sites and different-day coverage among sites would seem to be appropriate as long as weather and seasonal effects are standardized among areas.

## Acknowledgments

We greatly appreciate the Wildman family, Dorothy Lewis, and Louis Duning for making it possible to work on their lands. Financial support was supplied by the John Cring Memorial Fund and the James B. Cope Research Fund at Earlham College. We thank John B. Iverson for his help during data analysis. John Blake, Sam Droege, John Faaborg, C. J. Ralph, Chandler S. Robbins, Scott Robinson, Frank Thompson, and Jared Verner provided helpful comments or advice on an earlier draft of the manuscript.