Point Count Modifications and Breeding Bird Abundances in Central Appalachian Forests[1]

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Abstract: The effects of point count duration and radius on detection of breeding birds were compared by recording all birds seen or heard within two consecutive 5-minute intervals and for fixed-radius (within 30 m) or unlimited radius counts. Counts were conducted on Green Ridge State Forest (GRSF) and Savage River State Forest (SRSF) in western Maryland. More than 70 percent of all detections during fixed- and unlimited-radius counts occurred within the first 5 minutes. There was little overall gain in species richness from counting an additional 5 minutes. With fixed-radius counts, eight species at GRSF and two at SRSF showed significant differences in detections between the first and second 5 minutes. Using unlimited-radius counts, the resultant larger sample had a higher number of bird species showing significant differences between the first and second 5 minutes, 23 at GRSF and 12 at SRSF. Still, minimal changes in overall rank of species abundance resulted from counting an additional 5 minutes. About 80 percent of all bird detections and several new species were recorded >30 m from the counting point. Twenty-seven species at each of the two State Forests had significantly different detections within the two distance intervals. Compared with fixed-radius counts, detections >30-m distance often brought the rank order of species abundance up or down depending on whether the species had proportionally higher detections in the first or second distance interval. A time-distance interaction occurred with unlimited-radius counts, with more bird species >30-m distance tallied more often in the second 5-minute interval, indicating a possible increase in detection error with increasing distance and time. Observers may be recording more audible, nearby individuals first and only later noting less audible, more distant individuals. Fixed-radius counts done for 5 minutes should provide reasonable indices to species richness and abundance in a particular habitat, whereas unlimited-radius counts would provide a more complete list of species present in a local region.

Point counts (PC) have been conducted at different time intervals, often from 2 to 20 minutes (Robbins 1981, Scott and Ramsey 1981, Verner and Ritter 1986). Longer counts are less sensitive to species-specific differences in song intensity or changes in song or call rates throughout the morning hours (Robbins 1981). Longer counts soon become inefficient, however, as few new species are added with time and potentially fewer counts are possible. Additionally, because of bird movements, there is the chance of multiple-counting or of recording new birds that move into counting range from outside the area (Granholm 1983). Shorter time durations at more sites could also lead to increased statistical power in hypothesis tests. On the other hand, too short a time interval results in a smaller sample of the bird assemblage with potentially many birds being missed, particularly if the singing intensity is low. This factor is of greater importance later in the morning when the frequency of singing is lower (Robbins 1981, Verner and Ritter 1986).

Additionally, a fixed-radius or unlimited-radius count is often selected over a variable-radius count. Unlimited-radius counts are reported to be an efficient means for measuring species richness and for accumulating total counts of birds (Verner 1985, Verner and Ritter 1985). The same can be said for fixed-radius counts, and because the counting area is known, this method may provide a better index of abundance. With fixed-radius counts, observers inexperienced with estimating distances have to learn only one distance. However, selection of an optimum radius can be difficult. Although delectability of many species does drop considerably after distances of 20-30 m, there are species-specific differences in detectability with distance (Gutzwiller 1991, Hayward and others 1991, Hutto and Mosconi 1981). Some species are more easily detected nearby while others are more so at a distance. Some bird species may also move toward or away from an observer, or remain hidden if near an observer. Observers may also record more audible or nearby individuals first and only later focus on less audible or more distant individuals. Radii used in previous studies also have been quite variable, often ranging to >100 in (Edwards and others 1981, Hutto and others 1986, Morrison and others 1987, Verner and Larson 1989). Additional methodological problems and biases have been covered elsewhere (Ralph and Scott 1981, Verner 1985, Verner and Ritter 1985). My objectives were to evaluate the effects of count duration and distance from counting point on observer detection of breeding bird species on State Forests in western Maryland.

Study Area and Methods

Study Area

Two western Maryland State Forests, Green Ridge and Savage River, located in the central Appalachian Mountains were selected for study. The 15,699-ha Green Ridge State Forest (GRSF) is located in eastern Allegany County, while the 21,613-ha Savage River State Forest (SRSF) is located approximately 35 km west of Green Ridge State Forest (GRSF) in northeastern Garrett County. Both forest landscapes consist of a patchwork of different anthropogenic features, forest types (primarily oak-hickory), and successional stages, often isolated by private inholdings and both natural and human-made corridors. Since the mid-1970's, managers at both State Forests have conducted inventories (Continuous Forest Inventory (CFI)) to collect data on forest growth, volume, and other conditions. Each State Forest was stratified by type and stand-size class through a combination of field typing and aerial photograph interpretation and was gridded using a 609.6-m interval grid. Grid intersections representing the center of a 0.08-ha forest habitat (CFI) plot were then selected at random and permanently marked in the field. A sample of

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these permanent points, i.e., 91.0 percent of the 210 GRSF-CFI plots and 77.6 percent of the 277 SRSF-CFI plots, was used for a count survey of breeding birds on the State Forests.

Observer Selection and Training

Prior to selection as an observer, individuals were initially screened for experience and competence in the identification of birds by sight and sound. Tapes of bird songs of species present on the study areas were made available to each observer for study upon arrival. Further checks on their aural identification skills were frequently made in the field during flagging of points prior to beginning counts. Furthermore, for the first few days of counts, as a further check and confidence-building exercise, pairs of observers often went to the same point. At the end of such a count the pair of observers would then compare results for consistency. Data forms also were checked weekly to detect any problems or unusual species identifications by observers.

The observers were also trained in estimating whether or not a certain detection was ≤30 m or >30 m from the counting point. This distance was often flagged at a point using a rangefinder or pacing. A rangefinder or pacing also was used to check the distance to borderline detections. Nevertheless, because most detections were aural, placing a detection ≤30 m or >30 m from the point was often based on observer experience.

Point Counts

Point counts were done in 1990 at GRSF and 1991 at SRSF, beginning in May and ending in July. A minimum of four counts per point were scheduled during the breeding season; i.e., all points would be counted in one counting cycle prior to beginning the second, third, or fourth cycle. To reduce the effects of observer bias, each of four observers attempted to visit each point only once during the breeding season. To minimize any temporal bias, the four visits were equally distributed throughout the morning count period as well as over the breeding season. Point counts began at sunrise and generally ended 4.5-5 hours later. No counts were conducted during a steady hard rain, in thick fog, or when wind speeds were >20 km/hour.

Generally, two to four observers conducted counts on each day of the week. Under best of conditions, one observer could usually complete 6 counts (maximum of 12) each morning. Travel time between counts was approximately 35 to 40 minutes. Counts began when the observer reached a point. Birds were tallied if they were detected during the counts or were present at the point but stopped vocalizing or flushed without returning on perceiving the observer; e.g., Ruffed Grouse (*Bonasa umbellus*). Spring migrants detected during their regular migration period., but not during the breeding season, were considered transients and were not included in data analysis. We tallied, but did not analyze, birds flying over the plots (fly-overs) that were unlikely to be using the plots. Point counts were conducted for a total of 10 minutes at each point. To evaluate the effects of a shorter-time duration, the 10-minute count was divided into two consecutive 5-minute intervals. Birds counted during the first 5 minutes were not included in the second 5-minute count. The two intervals were combined for a 10-minute count. Observers also recorded birds as either within the 30-m radius or outside it. Birds moving into or out of a distance interval were counted only within the interval where first detected. Point count results within the two distance intervals, 0-30 m and >30 m, were added for unlimited-radius counts.

Statistical Analysis

To compare whether a species was more likely to be detected during the first or second 5 minutes of a 10-minute count or ≤30 m or >30 m of the counting point, species detections in each category were tested for significance with continuity adjusted Chi-square (χ^2) analysis (Siegel and Castellan 1988). The total number of detections or sample size can markedly influence the species richness (number of species) of an assemblage. Therefore, rarefraction was used to estimate species richness based on a standard number of detections (James and Rathbun 1981, Ludwig and Reynolds 1988). In order to compare 5- and 10-minute, and fixed- and unlimited-radius counts, I used a sample of n = 1314, i.e., the total detections for 5-minute, fixed-radius counts at SRSF, which is the smallest number of detections of the different count categories.

Results

Count Duration

Using fixed-radius counts and the overall proportion of bird detections during the first and second 5 minutes of a 10-minute count as a bench mark, the number of species on the State Forests having proportionally higher detections than the bench mark in the first 5 minutes was almost equal, 44.6 percent at SRSF to 50.0 percent at GRSF, to those having higher detections during the latter 5 minutes (*tables 1* and *2*). During the first 5 minutes, 70.5 percent (SRSF) and 75.6 percent (GRSF) of all bird detections were tallied. There was only a two species gain at GRSF (3.7 percent), and a four species gain at SRSF (6.6 percent) from the extra effort of counting 5 additional minutes. Based on rarefraction estimation, most of this increase can be explained by the larger sample resulting from counting longer. A gain of one species (1.6 percent at SRSF and 1.9 percent at GRSF) still occurred with the longer count after the number of detections was standardized. Few species, eight at GRSF and two at SRSF, had detectability patterns different than expected between the first and second 5 minutes. However, these species showed the same consistent patterns even when using different count radii (fixed or unlimited) at a State Forest or when using the same count methodology at different State Forests (*tables 1-4*). Furthermore, counting the extra 5 minutes for a 10-minute count had no major observable effect on the rank order of species abundance when compared with 5-minute counts (*tables 1* and *2*).

Using unlimited-radius counts and the overall proportion of bird detections during the first and second 5 minutes of a 10-minute count as a bench mark, the percentage of species with proportionally greater detections than the bench mark in the first versus the second 5 minutes was less than that with fixed-radius counts (*tables 3* and *4*). Only 34.7 percent (GRSF)

Table 1--*Total number of detections, relative abundance (percent), and rank order of bird species abundance by count duration on Green Ridge State Forest (GRSF) based on 191 fixed-radius counts done four times during the 1990 breeding season. Italicized values are significantly (P < 0.05) different between time intervals; all others not italicized are insignificant. Sample sizes ≤21 were too small for analysis and were eliminated from the table*

Species[a]	0-5 minutes			> 5-10 minutes			0-10 minutes		
	n	Pct	Rank	*n*	Pct	Rank	*n*	Pct	Rank
Detections greatest in 0-5 minutes									
Cedar Waxwing[b]	***25***	1.68	20	***1***	0.21	22	26	1.32	19
Ovenbird[b]	***116***	7.80	2	***17***	3.54	7	133	6.76	2
Hooded Warbler	27	1.81	19	4	0.83	19	31	1.58	17
American Redstart	47	3.16	12	7	1.46	16	54	2.74	13
Acadian Flycatcher[b]	***62***	4.17	8	***10***	2.08	14	72	3.66	10
Red-eyed Vireo[b,c]	***155***	10.42	1	***34***	7.08	1	189	9.60	1
Northern Cardinal	21	1.41	21	5	1.04	18	26	1.32	19
Rufus-sided Towhee	83	5.58	5	21	4.38	6	104	5.28	6
Indigo Bunting	53	3.56	10	14	2.92	10	67	3.40	11
Pine Warbler	37	2.49	15	10	2.08	14	47	2.39	15
Blue-gray Gnatcatcher	85	5.71	4	25	5.21	4	110	5.59	5
Wood Thrush	78	5.24	7	23	4.79	5	101	5.13	7
Great Crested Flycatcher	33	2.22	17	10	2.08	14	43	2.18	16
Detections greatest in 5-10 minutes									
Eastern Wood-Pewee	44	2.96	13	15	3.13	9	59	3.00	12
Worm-eating Warbler	87	5.85	3	33	6.88	2	120	6.10	3
White-breasted Nuthatch	31	2.08	18	12	2.50	12	43	2.18	16
Hairy Woodpecker	20	1.34	22	8	1.67	15	28	1.42	18
Scarlet Tanager	81	5.44	6	34	7.08	1	115	5.84	4
Black-capped Chickadee	38	2.55	14	16	3.33	8	54	2.74	13
Chipping Sparrow	34	2.28	16	15	3.13	9	49	2.49	14
Brown Creeper	20	1.34	22	11	2.29	13	31	1.58	17
Tufted Titmouse	***49***	3.29	11	***27***	5.63	3	76	3.86	9
Brown-headed Cowbird[b]	***59***	3.97	9	***34***	7.08	1	93	4.73	8
Blue Jay	15	1.01	24	10	2.08	14	25	1.27	20
Red-bellied Woodpecker[b]	***13***	0.87	26	***12***	2.50	12	25	1.27	20
American Goldfinch[b]	***12***	0.81	27	***13***	2.71	11	25	1.27	20
Total detections	1488	100.00		480	100.02		1968	100.04	
Total species	54						56		
E (S_{1314})[d]	53						54		

[a] Species are listed by decreasing proportion of detections within the first 5-min interval. The division of species between the two time intervals was determined by comparison of the proportion of detections of each species with the proportion of all species detections within each interval.

[b] Species showing the same significant difference with fixed- and unlimited-radius PCs at GRSF.

[c] Species showing the same significant difference with fixed-radius PCs at GRSF and Savage River State Forest.

[d] Rarefraction estimate of number of bird species based on $n = 1314$ individuals.

to 38.1 percent (SRSF) of the total number of bird species had proportionally greater detections during the first 5 minutes, 6.5 percent (SRSF) to 15.3 percent (GRSF) less than that observed with fixed-radius counts. Over 60 percent (61.9 percent SRSF to 65.3 percent GRSF) of the bird species had proportionally more detections than the bench mark in the second 5 minutes. There were 71.7 percent (SRSF) to 75.0 percent (GRSF) of overall bird detections tallied during the first 5 minutes, similar to fixed-radius counts. There were 10 more species (13.5 percent) observed, however, during the additional 5 minutes of counting at SRSF and no increase in numbers of species at GRSF. Rarefraction estimation indicated that this result was also greatly influenced by the larger sample, with only one species at GRSF and two species at SRSF (1.7 percent GRSF to 3.1 percent SRSF) added for the extra effort of counting after number of detections was standardized. Compared with fixed-radius counts, a larger number of species showed significant differences in detectabilities between the 0 to 5-minute and >5 to 10-minute categories, 23 at GRSF and 12 at SRSF, possibly related to larger samples. Again, these species exhibited consistent detectability patterns between fixed- and unlimited-radius counts at a State Forest and between State Forests when using the same count methodology (*tables 1-4*). In spite of the greater number of significant differences, I observed no major changes in rank order of species abundance resulting from counting an additional 5 minutes (*tables 3* and *4*).

Count Radius

The inclusion of birds detected >30 m from the counting point had a great influence on all parameters (*tables 5* and *6*). Using 10-minute counts and the overall proportion of

Table 2--*Total number of detections, relative abundance (percent), and rank order of bird species abundance by count duration on Savage River State Forest (SRSF) based on 215 fixed-radius counts done four times during the 1991 breeding season. Italicized values are significantly (P <0.05) different between time intervals, all others not italicized are* insignificant. *Sample sizes ≤17 were too small for analysis and were eliminated from the table*

Species[a]	0-5 minutes			> 5-10 minutes			0-10 minutes		
	n	Pct	Rank	*n*	Pct	Rank	*n*	Pct	Rank
Detections greatest in 0-5 minutes									
Chipping Sparrow	***21***	1.60	16	***2***	0.36	20	23	1.23	21
Golden-crowned Kinglet	19	1.45	18	2	0.36	20	21	1.13	22
Veery	35	2.66	12	8	1.45	14	43	2.31	13
Eastern Wood-Pewee	41	3.12	10	10	1.82	13	51	2.74	9
Red-eyed Vireo[b,c]	***221***	16.82	1	***62***	11.27	1	283	15.18	1
Scarlet Tanager	70	5.33	4	21	3.82	6	91	4.88	4
Acadian Flycatcher	74	5.63	3	26	4.73	3	100	5.36	3
Ovenbird	113	8.60	2	41	7.45	2	154	8.26	2
Hooded warbler	48	3.65	7	19	3.45	7	67	3.59	6
Black-throated Green Warbler	20	1.52	17	8	1.45	14	28	1.50	18
Black-capped Chickadee	17	1.29	20	7	1.27	15	24	1.29	20
Black-throated Blue Warbler	55	4.19	5	23	4.18	5	78	4.18	5
Detections greatest in 5-10 minutes									
White-breasted Nuthatch	18	1.37	19	8	1.45	14	26	1.39	19
Indigo Bunting	39	2.97	11	18	3.27	8	57	3.06	8
Black-and-white Warbler	42	3.20	9	21	3.82	6	63	3.38	7
Rufous-sided Towhee	52	3.96	6	26	4.73	3	78	4.18	5
Wood Thrush	32	2.44	13	16	2.91	9	48	2.58	11
Gray Catbird	25	1.90	15	13	2.36	12	38	2.04	14
Chestnut-sided Warbler	28	2.13	14	15	2.73	10	43	2.31	13
Canada Warbler	13	0.99	22	7	1.27	15	20	1.07	23
American Redstart	43	3.27	8	24	4.36	4	67	3.59	6
Brown-headed Cowbird	16	1.22	21	10	1.82	13	26	1.39	19
Common Yellowthroat	28	2.13	14	19	3.45	7	47	2.52	12
Solitary Vireo	28	2.13	14	21	3.82	6	49	2.63	10
Cedar Waxwing	18	1.37	19	14	2.55	11	32	1.72	16
Rose-breasted Grosbeak	19	1.45	18	15	2.73	10	34	1.82	15
Magnolia Warbler	17	1.29	20	14	2.55	11	31	1.66	17
Total detections	1314	99.98		550	99.97		1864	99.93	
Total species	61						65		
$E(S_{1314})$[d]	61						62		

[a] Species are listed by decreasing proportion of detections within the first 5-minute interval. The division of species between the two time intervals was determined by comparison of the proportion of detections of each species with the proportion of all species detections within each interval.

[b] Species showing the same significant difference with fixed- and unlimited-radius point counts at SRSF.

[c] Species showing the same significant difference with fixed-radius point counts at Green Ridge State Forest and SRSF.

[d] Rarefraction estimate of number of bird species based on n = 1314 individuals.

Table 3--*Total number of detections, relative abundance (percent), and rank order of bird species abundance by count duration on Green Ridge State Forest (GRSF) based on 191 unlimited-radius counts done four times during the 1990 breeding season. Italicized values are significantly (P < 0.05) different between time intervals; all others not italicized are insignificant. Sample sizes ≤20 were too small for analysis and were eliminated from the table*

Species[a]	0-5 minutes			>5-10 minutes			0-10 minutes		
	n	Pct	Rank	*n*	Pct	Rank	*n*	Pct	Rank
Detections greatest in 0-5 minutes									
Cedar Waxwing[b]	***50***	0.66	30	***3***	0.12	40	53	0.52	35
Yellow-breasted Chat	***46***	0.61	32	***6***	0.24	38	52	0.51	36
Rose-breasted Grosbeak	18	0.24	43	3	0.12	40	21	0.21	46
Field Sparrow	47	0.62	31	8	0.32	36	55	0.54	34
Wood Thrush	***628***	8.27	3	***123***	4.86	5	751	7.42	3
Ovenbird[b,c]	***661***	8.71	2	***132***	5.22	2	793	7.84	2
Red-eyed Vireo[b,c]	***690***	9.09	1	***142***	5.61	1	832	8.22	1
Solitary Vireo	24	0.32	42	5	0.20	39	29	0.29	43
Rufous-sided Towhee	***340***	4.48	7	***78***	3.08	13	418	4.13	8
Eastern Wood-Pewee[c]	***390***	5.14	5	***93***	3.68	10	483	4.77	5
Scarlet Tanager	***531***	7.00	4	***128***	5.06	3	659	6.51	4
Acadian Flycatcher[b]	***232***	3.06	11	***56***	2.21	17	288	2.85	11
Prairie Warbler	76	1.00	27	19	0.75	29	95	0.94	28
Brown Creeper	78	1.03	26	24	0.95	27	102	1.01	27
Common Yellowthroat	28	0.37	39	9	0.36	35	37	0.37	41
Indigo Bunting	238	3.14	10	78	3.08	13	316	3.12	10
Detections greatest in 5-10 minutes									
Blue-gray Gnatcatcher	168	2.21	14	56	2.21	17	224	2.21	16
American Crow	314	4.14	8	112	4.43	6	426	4.21	7
Tufted Titmouse	349	4.60	6	127	5.02	4	476	4.70	6
Hooded Warbler	83	1.09	25	30	1.19	24	113	1.12	25
Pine Warbler	130	1.71	20	47	1.86	19	177	1.75	21
Chipping Sparrow	202	2.66	12	74	2.93	14	276	2.73	12
Mourning Dove	78	1.03	26	29	1.15	25	107	1.06	26
Northern Cardinal	116	1.53	21	44	1.74	20	160	1.58	22
American Redstart	91	1.20	24	35	1.38	22	126	1.25	24
Louisiana Waterthrush	31	0.41	37	12	0.47	32	43	0.42	38
Worm-eating Warbler	281	3.70	9	110	4.35	7	391	3.86	9
Eastern Phoebe	25	0.33	41	10	0.40	34	35	0.35	42
Gray Catbird	30	0.40	38	12	0.47	32	42	0.42	39
Wild Turkey	27	0.36	40	11	0.43	33	38	0.38	40
Carolina Wren	71	0.94	28	31	1.23	23	102	1.01	27
Great Crested Flycatcher[c]	***191***	2.52	13	***84***	3.32	11	275	2.72	13
Yellow-throated Vireo	34	0.45	36	15	0.59	30	49	0.48	37
Black-capped Chickadee	***100***	1.32	23	*48*	1.90	18	148	1.46	23
Blue Jay	***146***	1.92	17	***71***	2.81	15	217	2.14	17
Pileated Woodpecker	***138***	1.82	18	*68*	2.69	16	206	2.04	19
American Robin	42	0.55	34	22	0.87	28	64	0.63	32
Cerulian Warbler	15	0.20	45	8	0.32	36	23	0.23	45
White-breasted Nuthatch[c]	***131***	1.73	19	***79***	3.12	12	210	2.08	18
Yellow-billed Cuckoo[c]	***152***	2.00	16	***97***	3.84	9	249	2.46	15
Brown-headed Cowbird[b,c]	***162***	2.13	15	***105***	4.15	8	267	2.64	14
Northern Flicker	***52***	0.69	29	***35***	1.38	22	87	0.86	29
Red-bellied Woodpecker[b]	***104***	1.37	22	***74***	2.93	14	178	1.76	20
Hairy Woodpecker[c]	***42***	0.55	34	***31***	1.23	23	73	0.72	31
American Goldfinch[b]	***35***	0.46	35	***27***	1.07	26	62	0.61	33
Downy Woodpecker	***43***	0.57	33	***36***	1.42	21	79	0.78	30
Black-billed Cuckoo	***15***	0.20	45	***13***	0.51	31	28	0.28	44
Northern Oriole	***10***	0.13	46	***11***	0.43	33	21	0.21	46
Total detections	7591	100.06		2529	100.02		10120	100.04	
Total species	72						72		
$E(S_{1314})$[d]	59						60		

[a] Species are listed by decreasing proportion of detections within the first 5-minute interval. The division of species between the two time intervals was determined by comparison of the proportion of detections of each species with the proportion of all species detections within each interval.

[b] Species showing the same significant difference with fixed- and unlimited-radius point counts at GRSF.

[c] Species showing the same significant difference with unlimited-radius point counts at GRSF and Savage River State Forest (SRSF).

[d] Rarefraction estimate of number of bird species based on $n = 1314$ individuals.

Table 4--*Total number of detections, relative abundance (percent), and rank order of bird species abundance by count duration on Savage River State Forest (SRSF) based on 215 unlimited-radius counts done four times during the 1991 breeding season. Italicized values are significantly (P < 0.05) different between time intervals; all others not italicized are insignificant. Sample sizes ≤18 were too small for analysis and were eliminated from the table*

Species[a]	0-5 minutes			>5-10 minutes			0-10 minutes		
	n	Pct	Rank	*n*	Pct	Rank	*n*	Pct	Rank
Detections greatest in 0-5 minutes									
Golden-crowned Kinglet	27	0.45	32	4	0.17	39	31	0.37	40
Least Flycatcher	25	0.41	34	5	0.21	38	30	0.35	41
Hermit Thrush	***74***	1.22	22	***16***	0.67	29	90	1.06	28
Red-eyed Vireo[b,c]	***843***	13.90	1	***222***	9.25	1	1065	12.58	1
Northern Parula	37	0.61	29	11	0.46	33	48	0.57	34
Eastern Wood-Pewee[c]	***340***	5.61	4	***103***	4.29	4	443	5.23	4
Yellow-throated Vireo	19	0.31	39	6	0.25	37	25	0.30	43
Ovenbird[c]	***492***	8.11	3	***156***	6.50	3	648	7.65	3
American Crow	***599***	9.88	2	***200***	8.34	2	799	9.44	2
Scarlet Tanager	299	4.93	5	100	4.17	5	399	4.71	5
Wood Thrush	221	3.64	7	78	3.25	8	299	3.53	8
Veery	181	2.98	10	65	2.71	11	246	2.91	11
Acadian Flycatcher	220	3.63	8	80	3.33	7	300	3.54	7
Louisiana Waterthrush	30	0.49	31	11	0.46	33	41	0.48	37
Hooded Warbler	166	2.74	12	62	2.58	13	228	2.69	12
Rufous-sided Towhee	237	3.91	6	90	3.75	6	327	3.86	6
Indigo Bunting	205	3.38	9	80	3.33	7	285	3.37	9
American Robin	33	0.54	30	13	0.54	31	46	0.54	35
Detections greatest in 5-10 minutes									
Canada Warbler	40	0.66	28	16	0.67	29	56	0.66	32
Carolina Wren	20	0.33	38	8	0.33	36	28	0.33	42
Chipping Sparrow	70	1.15	23	28	1.17	25	98	1.16	27
Black-throated Blue Warbler	180	2.97	11	73	3.04	10	253	2.99	10
Blue-gray Gnatcatcher	26	0.43	33	12	0.50	32	38	0.45	39
Common Yellowthroat	103	1.70	15	48	2.00	17	151	1.78	18
Tufted Titmouse	76	1.25	20	36	1.50	22	112	1.32	23
Black-and-white Warbler	114	1.88	14	55	2.29	14	169	2.00	15
Solitary Vireo	70	1.15	23	35	1.46	23	105	1.24	24
Rose-breasted Grosbeak	121	2.00	13	62	2.58	13	183	2.16	14
Blue Jay	101	1.67	16	53	2.21	15	154	1.82	17
Field Sparrow	40	0.66	28	21	0.88	27	61	0.72	31
Black-capped Chickadee	83	1.37	19	44	1.83	19	127	1.50	20
Chestnut-sided Warbler	76	1.25	20	41	1.71	20	117	1.38	22
Black-throated Green Warbler	92	1.52	18	50	2.08	16	142	1.68	19
Gray Catbird	65	1.07	24	36	1.50	11	101	1.19	26
Magnolia Warbler	45	0.74	27	25	1.04	26	70	0.83	30
Wild Turkey	18	0.30	40	10	0.42	34	28	0.33	42
White-breasted Nuthatch[c]	***75***	1.24	21	***45***	1.88	18	120	1.42	21
Northern Cardinal	24	0.40	35	15	0.63	30	39	0.46	38
Pileated Woodpecker	46	0.76	26	29	1.21	24	75	0.89	29
American Redstart	***100***	1.65	17	***64***	2.67	12	164	1.94	16
Cedar Waxwing	***62***	1.02	25	***40***	1.67	21	102	1.20	25
Brown-headed Cowbird[c]	***114***	1.88	14	***76***	3.17	9	190	2.24	13
Downy Woodpecker	30	0.49	31	21	0.88	27	51	0.60	33
Song Sparrow	11	0.18	43	8	0.33	36	19	0.22	45
Cerulian Warbler	17	0.28	41	13	0.54	31	30	0.35	41
Mourning Dove	17	0.28	41	13	0.54	31	30	0.35	41
Great Crested Flycatcher[c]	22	0.36	37	***17***	0.71	28	39	0.46	38
Northern Flicker	10	0.16	44	9	0.38	35	19	0.22	45
Hairy Woodpecker[c]	***23***	0.38	36	***21***	0.88	27	44	0.52	36
Yellow-billed Cuckoo[c]	***10***	0.16	44	***12***	0.50	32	22	0.26	44
Total detections	6065	100.03		2399	100.00		8464	99.92	
Total species	74						84		
$E(S_{1314})$[d]	64						66		

[a] Species are listed by decreasing proportion of detections within the first 5-min interval. The division of species between the two time intervals was by comparison of the proportion of detections of each species with the proportion of all species detections within each interval.

[b] Species showing the same significant difference with fixed- and unlimited-radius PCs at SRSF.

[c] Species showing the same significant difference with unlimited-radius PCs at Green Ridge State Forest and SRSF.

[d] Rarefraction estimate of number of bird species based on $n = 1314$ individuals.

Table 5--*Total number of detections, relative abundance (percent), and rank order of bird species abundance by plot radius on Green Ridge State Forest (GRSF) based on 191 10-minute counts done four times during the 1990 breeding season. Italicized values are significantly (P < 0.05) different between distance intervals; all others not italicized are insignificant. Sample sizes≤26 were too small for analysis and were eliminated from the table*

Species[a]	0-30 m			>30 m			Unlimited		
	n	Pct	Rank	*n*	Pct	Rank	*n*	Pct	Rank
Detections greatest in 0-30 m									
Blue-gray Gnatcatcher[b]	***110***	5.59	5	***114***	1.40	21	224	2.21	16
Cedar Waxwing	***26***	1.32	19	***27***	0.33	40	53	0.52	35
American Redstart[b]	***54***	2.74	13	***72***	0.88	28	126	1.25	24
American Goldfinch	***25***	1.27	20	***37***	0.45	36	62	0.61	33
Hairy Woodpecker	***28***	1.42	18	***45***	0.55	34	73	0.72	31
Black-capped Chickadee	***54***	2.74	13	***94***	1.15	23	148	1.46	23
Gray Catbird[b]	***15***	0.76	23	***27***	0.33	40	42	0.42	39
Brown-headed Cowbird[c]	***93***	4.73	8	***174***	2.13	16	267	2.64	14
Solitary Vireo	9	0.46	26	20	0.25	41	29	0.29	43
Worm-eating Warbler	***120***	6.10	3	***271***	3.32	9	391	3.86	9
Brown Creeper	***31***	1.58	17	***71***	0.87	29	102	1.01	27
Yellow-throated Vireo	14	0.71	24	35	0.43	37	49	0.48	37
Hooded Warbler	***31***	1.58	17	***82***	1.01	26	113	1.12	25
Pine Warbler	***47***	2.39	15	***130***	1.59	20	177	1.75	21
Acadian Flycatcher[b]	***72***	3.66	10	***216***	2.65	14	288	2.85	11
Rufous-sided Towhee	***104***	5.28	6	***314***	3.85	8	418	4.13	8
Red-eyed Vireo[b]	***189***	9.60	1	***643***	7.88	3	832	8.22	1
American Robin	14	0.71	24	50	0.61	32	64	0.63	32
Indigo Bunting	67	3.40	11	249	3.05	10	316	3.12	10
White-breasted Nuthatch	43	2.18	16	167	2.05	17	210	2.08	18
Detections greatest in >30 m									
Louisiana Waterthrush	8	0.41	27	35	0.43	37	43	0.42	38
Chipping Sparrow	49	2.49	14	227	2.78	13	276	2.73	12
Scarlet Tanager	115	5.84	4	544	6.67	4	659	6.51	4
Prairie Warbler	16	0.81	22	79	0.97	27	95	0.94	28
Ovenbird	133	6.76	2	660	8.09	1	793	7.84	2
Downy Woodpecker	13	0.66	25	66	0.81	30	79	0.78	30
Northern Cardinal	26	1.32	19	134	1.64	19	160	1.58	22
Common Yellowthroat	6	0.31	28	31	0.38	38	37	0.37	41
Tufted Chickadee	76	3.86	9	400	4.90	7	476	4.70	6
Great Crested Flycatcher	43	2.18	16	232	2.84	11	275	2.72	13
Red-bellied Woodpecker	25	1.27	20	153	1.88	18	178	1.76	20
Wood Thrush[b]	***101***	5.13	7	***650***	7.97	2	751	7.42	3
Carolina Wren	13	0.66	25	89	1.09	24	102	1.01	27
Eastern Wood-Pewee[b]	***59***	3.00	12	***424***	5.20	5	483	4.77	5
Blue Jay[b]	***25***	1.27	20	***192***	2.35	15	217	2.14	17
Yellow-breasted Chat	5	0.25	29	47	0.58	33	52	0.51	36
Yellow-billed Cuckoo	***19***	0.97	21	***230***	2.82	12	249	2.46	15
Pileated Woodpecker[b]	***14***	0.71	24	***192***	2.35	15	206	2.04	19
Field Sparrow[b]	***3***	0.15	31	***52***	0.64	31	55	0.54	34
Northern Flicker	***3***	0.15	31	***84***	1.03	25	87	0.86	29
American Crow[b]	***8***	0.41	27	***418***	5.12	6	426	4.21	7
Mourning Dove[b]	***1***	0.05	33	***106***	1.30	22	107	1.06	26
Black-billed Cuckoo	***0***			***28***	0.34	39	28	0.28	44
Eastern Phoebe	***0***			***35***	0.43	37	35	0.35	42
Wild Turkey[b]	***0***			***38***	0.47	35	38	0.38	40
Total detections	1968	100.04		8152	100.31		10120	100.04	
Total species	56						72		
$E(S_{1314})$[d]	54						60		

[a] Species are listed by decreasing proportion of detections within the 0-30 m distance interval. The division of species between the two distance intervals was determined by comparison of the proportion of detections of each species with the proportion of all species detections within each interval.

[b] Species showing the same significant differences with 10-minute point counts at GRSF and Savage River State Forest (SRSF).

[c] Species showing opposite significant differences with 10-minute point counts at GRSF and SRSF.

[d] Rarefraction estimate of number of bird species based on $n = 1314$ individuals.

Table 6--*Total number of detections, relative abundance (percent), and rank order of bird species abundance by plot radius on Savage River State Forest (SRSF) based on 215 10-minute counts done four times during the 1991 breeding season. Italicized values are significantly (P < 0.05) different between distance intervals; all others not italicized are insignificant. Sample sizes ≤23 were too small for analysis and were eliminated from the table.*

Species[a]	0-30 m			>30 m			Unlimited		
	n	Pct	Rank	*n*	Pct	Rank	*n*	Pct	Rank
Detections greatest in 0-30 m									
Golden-crowned Kinglet	***21***	1.13	22	***10***	0.15	45	31	0.37	40
Solitary Vireo	***49***	2.63	10	***56***	0.85	28	105	1.24	24
Blue-gray Gnatcatcher[b]	***17***	0.91	24	***21***	0.32	39	38	0.45	39
Magnolia Warbler	***31***	1.66	17	***39***	0.59	31	70	0.83	30
Yellow-throated Vireo	***11***	0.59	28	***14***	0.21	43	25	0.30	43
American Redstart[b]	***67***	3.59	6	***97***	1.47	20	164	1.94	16
Gray Catbird[b]	***38***	2.04	14	***63***	0.95	27	101	1.19	26
Black-and-white Warbler	***63***	3.38	7	***106***	1.61	17	169	2.00	15
Chestnut-sided Warbler	***43***	2.31	13	***74***	1.12	25	117	1.38	22
Louisiana Waterthrush	15	0.80	26	***26***	0.39	37	41	0.48	37
Canada Warbler	20	1.07	23	***36***	0.55	32	56	0.66	32
Hairy Woodpecker	15	0.80	26	29	0.44	35	44	0.52	36
Acadian Flycatcher[b]	***100***	5.36	3	***200***	3.03	10	300	3.54	7
Carolina Wren	9	0.48	30	19	0.29	40	28	0.33	42
Cedar Waxwing[b]	***32***	1.72	16	***70***	1.06	26	102	1.20	25
Common Yellowthroat	***47***	2.52	12	***104***	1.58	18	151	1.78	18
Black-throated Blue Warbler	***78***	4.18	5	***175***	2.65	11	253	2.99	10
Cerulian Warbler	9	0.48	30	21	0.32	39	30	0.35	41
Hooded Warbler[b]	***67***	3.59	6	***161***	2.44	13	228	2.68	12
Least Flycatcher	8	0.43	31	22	0.33	38	30	0.35	41
Red-eyed Vireo[b]	***283***	15.18	1	***782***	11.85	2	1065	12.58	1
Northern Cardinal	10	0.54	29	29	0.44	35	39	0.46	38
Rufous-sided Towhee	78	4.18	5	249	3.77	7	327	3.86	6
Ovenbird	154	8.26	2	494	7.48	3	648	7.65	3
Chipping Sparrow	23	1.23	21	75	1.14	24	98	1.16	27
Scarlet Tanager	91	4.88	4	308	4.67	5	399	4.71	5
Detections greatest in >30 m									
White-breasted Nuthatch	26	1.39	19	94	1.42	22	120	1.42	21
Downy Woodpecker	11	0.59	28	40	0.61	30	51	0.60	33
Great Crested Flycatcher	8	0.43	31	31	0.47	33	39	0.46	38
Indigo Bunting	57	3.06	8	228	3.45	8	285	3.37	9
Black-throated Green Warbler	28	1.50	18	114	1.73	16	142	1.68	19
Black-capped Chickadee	24	1.29	20	103	1.56	19	127	1.50	20
Northern Parula	9	0.48	30	39	0.59	31	48	0.57	34
Rose-breasted Grosbeak	34	1.82	15	149	2.26	14	183	2.16	14
Veery	43	2.31	13	203	3.08	9	246	2.91	11
Wood Thrush[b]	***48***	2.57	11	***251***	3.80	6	299	3.53	8
American Robin	7	0.38	32	39	0.59	31	46	0.54	35
Tufted Titmouse	16	0.86	25	96	1.45	21	112	1.32	23
Brown-headed Cowbird[c]	***26***	1.39	19	***164***	2.48	12	190	2.24	13
Hermit Thrush	***11***	0.59	28	***79***	1.20	23	90	1.06	28
Eastern Wood-Pewee[b]	***51***	2.74	9	***392***	5.94	4	443	5.23	4
Field Sparrow[b]	***6***	0.32	33	***55***	0.83	29	61	0.72	31
Blue Jay[b]	***12***	0.64	27	***142***	2.15	15	154	1.82	17
Pileated Woodpecker[b]	***5***	0.27	34	***70***	1.06	26	75	0.89	29
Wild Turkey[b]	***1***	0.05	38	***27***	0.41	36	28	0.33	42
American Crow[b]	***11***	0.59	28	***788***	11.94	1	799	9.44	2
Mourning Dove[b]	***0***			***30***	0.45	34	30	0.35	41
Total detections	1864	99.92		6600	99.99		8464	99.92	
Total species	65						84		
$E(S_{1314})$[d]	62						66		

[a] Species are listed by decreasing proportion of detections within the 0-30 m distance interval. The division of species between the two distance intervals was determined by comparison of the proportion of detections of each species with the proportion of all species detections within each interval.

[b] Species showing the same significant differences with 10-minute point counts at Green Ridge State Forest (GRSF) and SRSF.

[c] Species showing opposite significant differences with 10-minute point counts at GRSF and SRSF.

[d] Rarefraction estimate of number of bird species based on $n = 1314$ individuals.

detections of 0-30 m and >30 m from the sampling point as a bench mark, 42.9 percent of the species at SRSF to 45.8 percent of the species at GRSF had more detections than the bench mark ≤30 m of the counting point. However, 78.0 percent (SRSF) to 80.6 percent (GRSF) of all bird detections were tallied >30 m from the counting point. Sixteen new species at GRSF and 19 at SRSF (approximately 29 percent increase) were added to the species list by including birds >30 m away. Based on rarefraction, the increase dropped to four new species at SRSF to 6 new species at GRSF (6.5 percent SRSF and 11.1 percent GRSF), indicating a large contribution due to sample size but with some species recorded only outside the 30-m radius. Including detections >30 m in a count had a marked effect on rank order of species abundance. If the species was tallied more frequently at ≤30 m, inclusion of detections at >30 m often brought the species rank order of abundance down for unlimited-radius counts, whereas the rank order of species whose detections were greater at >30-m distance often increased in unlimited-radius counts over that within fixed-radius counts (*tables 5* and *6*). Species detected more frequently at ≤30 m from the counting point were often those whose songs or calls cannot be heard very well >30 m away (e.g., Blue-gray Gnatcatcher (*Pilioptila caerulea*)). Species detected more often at >30-m distance included many whose calls or songs carry great distances (e.g., Blue Jay (*Cyanocitta cristata*), American Crow (*Corvus brachyrhynchos*)) or are difficult to approach (e.g., Wild Turkey (*Meleagris gallopavo*)). Species having significant differences exhibited the same trends in detections regardless of State Forest, except for the Brown-headed Cowbird (*Molothrus ater*). At GRSF the cowbird was detected more frequently at ≤30 m from the counting point, whereas at SRSF it was detected more frequently at >30 m from the counting point. This factor might be related to differences between the two State Forests in distribution of preferred breeding habitat or concentrations of livestock on which this species depends for foraging (Verner and Ritter 1983).

Interactions Between Count Duration and Radius

I wanted to determine the association between number of species with detections either proportionally higher or lower than the distance bench mark in each distance interval and count duration. I investigated this question by analyzing those species having proportionally higher detections within 30 m and >30 m of the sampling point separately to minimize the effect of distance from the counting point on detectability. I first selected those species whose detections were proportionally higher ≤30 m from the counting point. I then determined the number that were proportionally higher or lower in the first or second 5 minutes, using the time bench marks. In the analysis, I assumed no difference in the number of nearby species within the two time intervals; therefore, half of the species should have proportionally higher detections in 0-5 minutes and the remainder >5-10 minutes. At GRSF, 33 bird species had proportionally higher detections ≤30 m from the counting point. Twelve (36.4 percent) were placed in the 0- to 5-minute interval, while 21 (63.6 percent) were in the >5- to 10-minute interval (χ^2 = 2.45, df = 1, P >0.05). At SRSF, 36 species had proportionally higher detections ≤30 m of the counting point. Of these, 15 (41.7 percent) had proportionally higher detections during the first 5 minutes, and 21 (58.3 percent) had proportionally higher detections during the latter 5 minutes (χ^2 = 1.00, df = 1, P >0.05). Within 30 m of the counting point, there was an apparent, but insignificant, trend for more species to have proportionally higher detections during the latter half of a 10-minute count.

However, when bird species with proportionally more detections >30-m distance were compared against the time interval, there were significant differences. At GRSF; 39 species had proportionally greater detections >30 m. Thirteen (33.3 percent) species had proportionally higher detections during the first 5 minutes, and 26 (66.7 percent) during the latter 5 minutes (χ^2 = 4.33, df = 1, P <0.05). At SRSF, 48 bird species had proportionally greater detections >30 m. Seventeen (35.4 percent) species had proportionally higher detections during the first 5 minutes, and 31 (64.6 percent) during the latter 5 minutes (χ^2 = 4.08, df = 1, P <0.05).

Discussion

Whether one uses fixed- or unlimited-radius counts, use of a shorter 5-minute count would seem most efficient for studies of forest birds in the central Appalachians. Little additional information was gained by counting for 10 minutes, because more than 70 percent of all detections occurred within the first 5 minutes. However, counts ≥5 minutes are reported to compensate better for diminished cue production later in the morning (Robbins 1981). Many of the species having higher detections than expected during the >5- to 10-minute interval (e.g., the Brown-headed Cowbird) generally had lower cue production than those with higher detections within the 0- to 5-minute interval. Anderson and Ohmart (1981) reported that 6 minutes was insufficient for censusing variable circular plots (120-m radius limit). They found that 7 and 8 minutes were apparently better because of a more thorough census, but the possibility existed that some of the later detections could actually be recounts. Using unlimited-radius counts, Verner and Ritter (1986) failed to show any significant decline in total counts during later hours with counts of 8 and 10 minutes. If the goal is to have as complete a species list as possible and rank order of species abundance is not a priority, the new species detected by longer counts might be worth the effort, particularly if travel time is considerable and repeat visits are not possible.

Major differences resulted from including birds detected at >30 m distance. The higher number of detections (approximately 80 percent) strongly influenced rank order of species abundance when compared with fixed-radius counts and resulted in 13 new species at SRSF to 18 new species at GRSF with 5-minute counts and 16 new species at GRSF to 19 new species at SRSF with 10-minute counts. Much of the increase is attributable to larger sample sizes. Compared with fixed-radius counts, bird species >30 m from the counting point had disproportionately higher detections in the latter 5 minutes of a 10-minute count. This result suggests that as area counted expands and count duration lengthens, counts of birds become more variable, possibly because observers

unintentionally recorded nearby birds first and only later focused on more distant birds. I have not seen any published data that would indicate a time-distance interaction in detectability among observers; however, intuitively such a result might be a natural outcome of the order in which cues are perceived or focused on by observers. There also may be more of a problem with multiple detections of the same distant individual or movement of birds into counting range with longer counts. It becomes increasingly difficult to monitor bird movements at great distances and over long time intervals. Additional errors also result because for certain particularly numerous species, pairs or trios of detections far from the observer will often be counted as a single one (R. W. Howe personal communication). This bias also contributed to the greater number of species showing differences in detections during the first versus the second 5 minutes of unlimited-radius counts. Nevertheless, detections >5 minutes did not seem to have a major effect on overall rank order of species abundance based on unlimited-radius counts.

Although there were species-specific differences in detectability with count duration and radius, fixed-radius counts conducted for 5 minutes would seem to offer a reasonable sample of most species and provide a rank order of species abundance that can be related to habitat. Unlimited-radius counts done for 5-10 minutes would provide a more complete sample of species in a local area. However, rank order of species abundance was markedly affected by counting birds >30-m from the sampling point. Furthermore, at greater distances and over longer time intervals, there would be a greater chance of multiple-counting the same bird. Additional work also needs to be done to understand the apparent observer bias in tallying nearby individuals first and more distant individuals later in the count. If this bias is further confirmed, unlimited-radius counts would be affected much more by count duration than fixed-radius counts, at least at the 30-m distance used in this study. Therefore, such counts should be long enough to sample distant individuals, but short enough to minimize multiple-recordings. In conclusion, it is important to recognize that no method is without certain inherent problems and biases, and that data obtained from using the method should be analyzed accordingly.

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