

Point Count Length and Detection of Forest Neotropical Migrant Birds¹

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Abstract: Comparisons of bird abundances among years or among habitats assume that the rates at which birds are detected and counted are constant within species. We use point count data collected in forests of the Mid-Atlantic states to estimate detection probabilities for Neotropical migrant bird species as a function of count length. For some species, significant differences existed among years or observers in both the probability of detecting the species and in the rate at which individuals are counted. We demonstrate the consequence that variability in species' detection probabilities can have on estimates of population change, and discuss ways for reducing this source of bias in point count studies.

The point count technique is commonly used for surveying bird populations. Because counts are made from a stationary location, an observer can concentrate fully on visual and aural detections of birds within a fixed or unlimited distance.

Point count length has not been standardized among surveys. Three-minute counts are used in the Breeding Bird Survey, which has been in operation throughout North America since the late 1960's (Robbins and others 1986). Among off-road studies conducted by other investigators, however, count length has ranged up to 20 minutes (Robbins and others 1989). For most species, the number of individuals counted at a point is a function of the time spent counting. Birds that are inconspicuous because of their distance from the point or that vocalize infrequently have a higher probability of being detected with longer counting periods. In addition, observers with less experience or hearing acuity may be more likely to detect birds when counting periods are longer. However, Scott and Ramsey (1981), Fuller and Langslow (1984), and Verner (1988) caution that the probability of counting birds more than once increases with increasing count length.

Analytical comparisons of species' abundances among years or among habitats assume that the rates at which birds are detected or counted are constant within species (Barker and Sauer, in these Proceedings). Detections of birds are affected by factors that influence singing frequency (e.g., time-of-day or season, weather conditions, and presence of conspecifics) or the perceptive abilities of observers (e.g., habitat, experience, and hearing acuity). Thus, an important consideration in the development of a protocol for bird surveys should be to set a count length that reduces variability in the probability of detecting the birds present at points.

In this paper, we use point count data collected in forests of the Mid-Atlantic states to estimate the probabilities of

detecting Neotropical migrant bird species at points as a function of count length. We test the effect of year and observer on species' detection probabilities and on the rates at which new detections of individuals are accumulated. Finally, for selected species we demonstrate the consequence that variation in detection probabilities can have on estimates of population change, and suggest how this source of bias can be reduced.

Methods

Bird Counts

The data used in our analyses were collected during 1979 through 1983 as part of a study on the effects of forest area on bird distribution (Robbins and others 1989). Bird counting points were established in mature forests ranging in area from 0.1 ha to >3,000 hectares within four physiographic regions in Maryland and adjacent counties in Pennsylvania, Virginia, and West Virginia (*fig. 1*). In most forests, a single point was established in the approximate center of the tract. In tracts >500 hectares, two or more points, at least 200 m from each other and from the forest edge, were established. The study sites selected included the major forest types of the Mid-Atlantic Region: upland deciduous forests, pine forests, mixed evergreen and deciduous forests, floodplain forests, and mountain swamps. In each year of the study, emphasis centered on sampling a wide range of forest areas within one physiographic region; thus no regions or forest types were sampled in all years of the study.

Each point was visited three times during 1 year of the study; the median date was June 5 for first visits to points, June 17 for second visits, and June 25 for third visits. The starting times for counts were varied among visits so that each point was sampled at different times during the early morning period (within 4 hours of sunrise). Visits were generally made by different observers to maximize the probability of detecting each species present. Over the 5 years of the study, eight different observers, each a skilled birder with previous experience in conducting standardized counts, assisted with data collection during one to four seasons.

On each visit, counts were made of all birds detected during a 20-minute period; birds clearly outside the habitat in which the point was located were excluded. For each species, counts were tallied separately for singing males, nonsinging adults (generally females), juveniles, and birds observed flying over the site. Relative locations of each bird detected were mapped for each 5-minute interval of the count period. With this technique for data recording, it was possible not only to determine in which 5-minute interval of the count period a species was first detected but the 5-minute intervals in which additional individuals of the species were detected. Mapping the relative locations of birds also helped to reduce the possibility of counting individuals more than once. After the count was completed, the observer recorded the cumulative counts of singing males and nonsinging adults for each species

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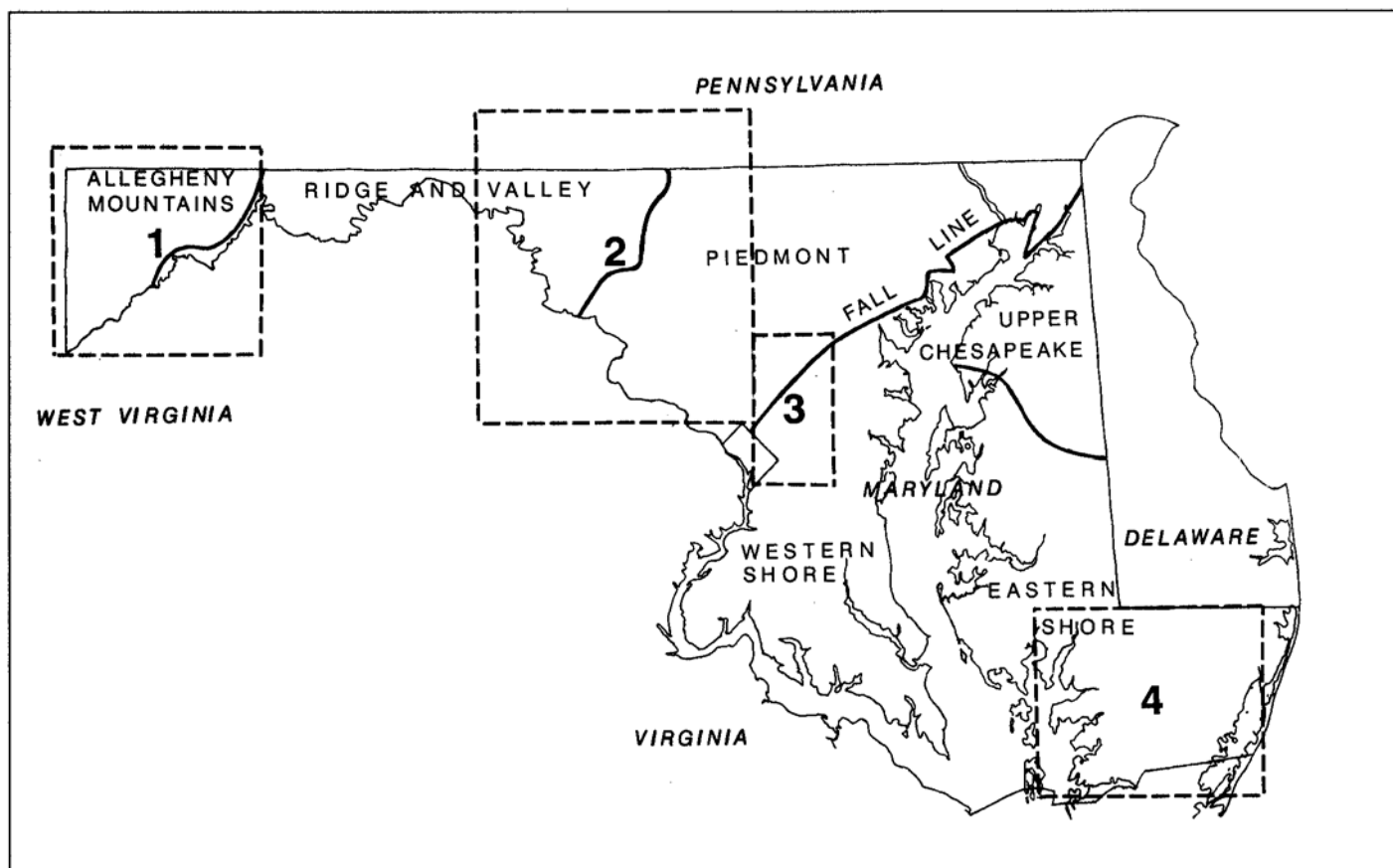


Figure 1--Location of the four physiographic regions of Maryland and adjacent states in which point counts were conducted, 1979-83 (Robbins and others 1989).

detected at the point. Species detected immediately before or after, but not during, the count period were noted.

Statistical Analyses

We used data collected at 454 points, each of which was sampled on three visits. The data for Neotropical migrant species extracted from the field sheets consisted of a cumulative count of number of individuals detected after 5, 10, 15, and 20 minutes of counting.

We used the Kaplan-Meier product limit estimator (Cox and Oakes 1984, Kaplan and Meier 1958) to estimate species' detection probabilities as a function of count length. We define a species' detection probability as the probability of detecting that species at a point given that the species is present. A species was considered present if it was detected within or outside (immediately before or after) the 20-minute count period on a visit to a point. In addition, if the species was detected during the first and third visits to a point but not on the second, it was assumed to have been present on the second visit. Because of the extensive observation at each point (a total of 1 hour of counting time during visits on 3 different days), we feel confident that there were few points at which a species was present but not detected and that, as a result, the detection probabilities estimated were minimally biased. The input data for each species consisted of the frequency distribution of the 5-minute intervals of first detection on counts; data from all visits to points were pooled for the analysis. Detection probabilities were calculated as the complement of

the survivor function from the Kaplan-Meier method (LIFETEST procedure, SAS Institute Inc. 1985). Approximate 95 percent confidence limits were obtained using the normal approximation to the distribution of a logistic transformation of the probabilities.

Detection probability functions were estimated by year and averaged across years to produce estimated probabilities of detecting each species after counting for 5, 10, 15, and 20 minutes. For the 14 species that were detected in at least one physiographic region in all years of the study, we used log rank tests to test the null hypothesis that detection probabilities for each region did not vary among years or observers. In addition, we used repeated-measures analysis of variance to test the effect of year and observer on the proportion of the total number of individuals of these species counted on a 20-minute visit to a point that were detected within 5, 10, and 15 minutes. Because the same set of observers was not used throughout the study, observer and year are confounded, making it impossible to independently assess their effects on the rates at which birds were detected.

We used Monte Carlo techniques (Hammersley and Handscomb 1964) to demonstrate for six widely distributed bird species that variation in detection probabilities can affect estimates of population trend. We simulated a survey in which counts were made at n points ($n = 100$ and $n = 200$), and then repeated in a subsequent year. Each species occurred at the same number of points in each year, but the probability of detecting the species was allowed to vary. Two

Table 1—Probability of detecting 14 species of forest Neotropical migrant birds within 5, 10, 15, and 20 minutes at points at which they were known to be present. The number of points is the number at which a species was detected (maximum 454); actual sample size for Kaplan-Meier analyses is the number of point-visits during which the species was detected.

Species name	Number of points	Probability of detecting within:			
		5 minutes	10 minutes	15 minutes	20 minutes
Yellow-billed Cuckoo	258	0.465	0.655	0.812	0.922
Great Crested Flycatcher	270	0.540	0.704	0.839	0.926
Eastern Wood-Pewee	294	0.611	0.752	0.854	0.920
Acadian Flycatcher	176	0.747	0.820	0.896	0.936
Blue-gray Gnatcatcher	112	0.580	0.728	0.862	0.931
Wood Thrush	323	0.784	0.882	0.939	0.971
Gray Catbird	171	0.615	0.779	0.893	0.936
Red-eyed Vireo	377	0.857	0.922	0.964	0.980
Worm-eating Warbler	79	0.507	0.671	0.877	0.929
Ovenbird	244	0.765	0.885	0.940	0.977
Kentucky Warbler	82	0.580	0.773	0.827	0.945
Common Yellowthroat	125	0.606	0.740	0.852	0.950
Scarlet Tanager	295	0.718	0.833	0.910	0.948
Indigo Bunting	184	0.582	0.726	0.845	0.912

20-minute counts were made at each point in each year; on each visit, the 5-minute interval in which a species was first detected was noted. The simulation was replicated 100 times.

We assumed that the point counts could be adequately modeled by a beta-binomial distribution; the year-specific, binomial detection probabilities are assumed to be beta random variables with parameters α and β . Thus the expected value of the detection probability is $\alpha/(\alpha + \beta)$. The Kaplan-Meier estimates of yearly species' detection probabilities for counts of different lengths were used to obtain method-of-moment estimates of α and β for the simulation.

The measure of trend we consider here is the absolute value of percentage change in frequency of occurrence. Because no actual trend in the simulated populations existed, any change in frequency of occurrence is due solely to variation

in the probability of detecting the species. Thus, the simulations demonstrate how variation in species' detection probabilities can lead to incorrect conclusions about population change, and the effect of count length on this source of bias. We summarize results using: (1) only the data from the fast visit and (2) data from both visits. In the latter case, a species was considered present at a point if it was detected on at least one visit.

Results

The estimates of species' detection probabilities after 5 minutes of counting ranged from 0.27 for Ruby-throated Hummingbird (*Archilochus colubris*), a widely distributed but inconspicuous species, to 0.92 for Northern Waterthrush (*Seiurus noveboracensis*), a species that occurs locally at relatively high densities in high-elevation swamps in Region 1. By the end of 15 minutes of counting, detection probabilities for nearly all species exceeded 0.80. Detection probabilities after counts of 5, 10, 15, and 20 minutes are shown in *table 1* for 14 species that occurred in all physiographic regions of the study. Detection probabilities for 20-minute counts are <1.0 because of instances in which species were detected immediately before or after but not within the counting periods, or in which species were not detected on second visits to points but were observed on visits one and three.

Log rank tests indicated that for some species significant differences in detection probabilities existed among years or observers; however, for no species were test results consistent across physiographic regions (*table 2*). Least square means of the proportions of individuals counted within 5, 10, or 15 minutes are presented (*table 3*) for species within physiographic regions for the years for which sufficient data were available; these represent the expected proportion of individuals of a species that would be detected in counts of 5, 10, or 15 minutes. Because the proportions are based on the total number of individuals counted within a 20-minute visit to a point (and thus forced to 1.0), we think that they are of limited use for assessing appropriate count length. However, differences among years or observers in the rates at which new individuals

Table 2—Significance of log-rank tests for differences among years or observers in the probability of detecting 14 bird species that occur in all physiographic regions sampled.

Species name	Region			
	1	2	3	4
Yellow-billed Cuckoo				*
Great Crested Flycatcher	**			**
Eastern wood-Pewee	***	***	***	
Acadian Flycatcher		***		*
Blue-gray Gnatcatcher				
Wood Thrush	***	*		
Gray Catbird		***		***
Red-eyed Vireo	**		*	*
Worm-eating Warbler			**	**
Ovenbird	**	*	*	
Kentucky Warbler				
Common Yellowthroat	***			
Scarlet Tanager			*	
Indigo Bunting	***	***		

*= $P<0.10$, **= $P<0.05$, ***= $P<0.01$

Table 3--The mean expected proportion of the total birds counted that were detected within 5, 10, and 15 minutes for species and physiographic regions for which there was sufficient data for analysis. Lower and upper bounds to the means were calculated as approximate confidence intervals. Significant year or observer effects within physiographic regions are indicated

Year	Observer	Proportion detected within:								
		5 minutes			10 minutes			15 minutes.		
		Mean	Lower	Upper	Mean	Lower	Upper	Mean	Lower	Upper
Yellow-billed Cuckoo										
Reg. 1		0.449	0.186	0.712	0.671	0.462	0.880	0.817	-	-
2		0.655	0.449	0.861	0.722	0.547	0.897	0.896	0.748	1.000
3		0.265	0.000	0.506	0.558	0.241	0.875	0.975	0.789	1.000
4	**	0.371	0.138	0.603	0.558	0.333	0.782	0.917	0.740	1.000
Great Crested Flycatcher										
Reg. 1		0.536	0.382	0.690	0.821	0.668	0.974	0.890	0.771	1.000
2	***	0.604	0.416	0.792	0.647	0.488	0.807	0.935	0.832	1.000
3		0.292	0.000	0.741	1.000	0.603	1.000	1.000	0.681	1.000
4		0.413	0.267	0.558	0.591	0.439	0.743	0.806	0.705	0.907
Eastern Wood-Pewee										
Reg. 1	*	0.544	0.409	0.679	0.616	0.505	0.727	0.957	0.901	1.000
2	*	0.663	0.539	0.787	0.811	0.714	0.909	0.879	0.807	0.951
3		0.506	0.205	0.807	0.650	0.421	0.880	0.810	0.633	0.988
4	*	0.409	0.214	0.603	0.750	0.590	0.910	0.911	0.853	0.969
Acadian Flycatcher										
Reg. 1	***	0.842	0.713	0.972	0.931	0.850	1.000	1.000	-	-
2		0.764	0.634	0.893	0.853	0.742	0.965	0.936	0.853	1.000
3		0.744	0.610	0.878	0.844	0.739	0.949	0.965	0.899	1.000
4	* *	0.605	0.511	0.699	0.748	0.671	0.826	0.946	0.902	0.990
Blue-gray Gnatcatcher										
Reg. 2		0.572	0.317	0.828	0.794	0.539	1.000	0.937	0.804	1.000
4		0.565	0.268	0.861	0.748	0.506	0.991	0.888	0.803	0.974
Wood Thrush										
Reg. 1		0.685	0.586	0.785	0.803	0.714	0.892	0.924	0.864	0.984
2		0.641	0.558	0.725	0.867	0.807	0.928	0.956	0.921	0.991
3		0.625	0.461	0.788	0.772	0.632	0.912	0.902	0.798	1.000
4	**	0.672	0.574	0.770	0.845	0.774	0.917	0.965	0.924	1.000
Gray Catbird										
Reg. 1	**	0.612	0.358	0.866	0.847	0.620	1.000	0.977	0.846	1.000
2		0.573	0.464	0.682	0.852	0.760	0.944	0.896	0.848	0.945
3		0.477	0.231	0.724	0.710	0.423	0.996	0.898	0.733	1.000
4		0.675	0.491	0.859	0.799	0.658	0.940	0.955	0.889	1.000
Red-eyed Vireo										
Reg. 1		0.768	0.686	0.851	0.902	0.839	0.966	0.961	0.923	0.998
2		0.688	0.567	0.810	0.815	0.715	0.914	0.932	0.880	0.985
3	**	0.690	0.584	0.797	0.829	0.743	0.915	0.880	0.822	0.939
4		0.678	0.611	0.746	0.801	0.752	0.850	0.921	0.889	0.953
Ovenbird										
Reg. 1		0.618	0.526	0.710	0.829	0.760	0.897	0.940	0.896	0.984
2	*** **	0.644	0.537	0.752	0.842	0.772	0.912	0.929	0.876	0.982
3	*	0.531	0.288	0.775	0.885	0.722	1.000	0.906	0.782	1.000
4		0.692	0.597	0.786	0.815	0.736	0.894	0.918	0.860	0.976
Common Yellowthroat										
Reg. 1		0.446	0.265	0.626	0.692	0.533	0.851	0.814	0.699	0.929
Scarlet Tanager										
Reg. 1	*	0.757	0.655	0.859	0.879	0.804	0.954	0.967	0.929	1.000
2		0.752	0.625	0.880	0.881	0.782	0.981	0.940	0.862	1.000
3		0.784	0.656	0.912	0.929	0.836	1.000	0.979	0.922	1.000
4		0.577	0.334	0.819	0.724	0.526	0.922	0.905	0.777	1.000
Indigo Bunting										
Reg. 1		0.597	0.470	0.725	0.763	0.654	0.873	0.862	0.779	0.945
2		0.538	0.354	0.722	0.685	0.521	0.849	0.940	0.867	1.000
3	**	1.000	0.245	1.000	1.000	0.481	1.000	1.000	0.406	1.000
4	*	0.520	0.358	0.682	0.661	0.523	0.798	0.898	0.779	1.000

*= $P < 0.10$, **= $P < 0.05$, ***= $P < 0.01$

are counted would bias estimates of abundance and limit the interpretation of trends. Tests for year or observer effects on the proportion of individuals counted within 5, 10, or 15 minutes indicated significant differences existed for some species, although not across all physiographic regions (*table 3*).

Simulations of between-year change in frequency of occurrence were based on the yearly Kaplan-Meier estimates of species' detection probabilities within regions for counts of 5, 10, 15 and 20 minutes (*table 4*). Because the number of points at which a species occurred was held constant between years in the simulations, changes in frequency of occurrence result solely from random variation in species' detection probabilities, and thus falsely indicate population change. The simulated change in frequency of occurrence varied greatly among species and physiographic regions (*table 5*). The average percentage change was low (<12 percent) for Red-eyed Vireo (*Vireo olivaceus*) in each of the three regions for which simulations were run, regardless of count length. However, for Great Crested Flycatcher (*Myiarchus crinitus*) in Region 1, differential detection probabilities resulted in average percentage differences in frequency of occurrence of 76 percent, when no population change actually existed.

For all species, the simulations show that false indications of trend could be reduced by increasing the length of time spent counting at points. False trends were also reduced by making a second visit to points and considering a species to be present at a point if it was detected on at least one of the two visits. In all cases, simulated changes in frequency of occurrence were reduced by 50 percent or greater by visiting points twice and counting for 10 minutes or longer. Results were less consistent across species and regions for two visits and 5-minute counts (*table 5*). Because, in our example, the numbers of points sampled and those at which species occurred were held constant between years, change in frequency of occurrence is not a function of sample size. Consequently, our results do not address the contribution of increased sample size to reduction of bias associated with variability in detection probabilities.

Discussion

Results of this study merit consideration by those designing point count studies for monitoring bird populations. First, in fixed-length counts, detection probabilities vary among species. For species with a low probability of detection, both the number of points at which the species is detected and the number of individuals counted for the species may be increased by increasing count length. If particular species are of interest or if good measures of species richness at individual points are required, count length can be optimized to address these objectives (Barker and others 1994; Barker and Sauer, in this volume). Second, within species, detection probabilities and the rates at which individuals are counted may vary among years, among observers, or among physiographic regions. In this study, yearly variations in detection probabilities may be a

result of differences among years in the set of observers conducting counts or in the set of points sampled. Differences in detection probabilities among physiographic regions likely result from regional differences in habitats or bird abundances. The consequence of the differences for monitoring programs is that variability in detection probabilities is a source of bias in estimates of population change. For example, indices of abundance can change strictly as a result of changes in detection probabilities, even when populations remain stable. Alternatively, if a species tends to become more detectable while populations decline (perhaps due to habitat alteration), then the index would falsely indicate relative population stability. In either case variation in detection probabilities may result in false conclusions about population trends.

We believe that an important criterion for the design of surveys for monitoring programs should be to reduce (if not eliminate) bias due to variation in detection probabilities. Stratification by physiographic regions or by habitats may help to minimize bias caused by spatial differences in detection probabilities (Barker and others 1994). Observer differences can be reduced to some extent by enlisting birders with previous experience in conducting timed counts or by providing training in identification and counting techniques; however in our study we found differences even among skilled observers in species' detection probabilities (*table 2*) and in the rates at which new individuals were counted. These results suggest that if assessment of population change is the study objective, the same observers should be used among years whenever possible.

Our simulations demonstrate that bias resulting from variation in species' detection probabilities can also be reduced by increasing the amount of time spent counting at points. For the six species for which we did simulations, there was a decided advantage to making two visits to determine species' presence at points; false trends in the number of points at which the species was detected could often be reduced by 50 percent for counts of 10 minutes or less if points were visited twice. However, if logistical concerns make travel to points difficult, extending count length to 15 or 20 minutes one of visit might be more efficient than revisiting points.

Often the time and resources available for sampling are limited and fixed; thus allocation of sampling effort represents a tradeoff between increasing species' detection probabilities at points (by increasing the time spent at points) and increasing the number of points sampled. Therefore, we strongly emphasize the importance of defining objectives prior to initiating a point count study so that sampling effort can be allocated to best address study goals.

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Table 4--Kaplan-Meier estimates of species detection probabilities, with approximate 95 percent confidence intervals. The mean and variance were used to estimate the parameters of the beta distribution for the simulation. The numbers 5, 10, 15, and 20 refer to point count periods in minutes.

Region 1					Region 2					Region 4					Mean and Variance	
1980	1981	1982	1983	Variance	1979	1980	1983	Variance	1981	1982	1983	Variance	1983	1982	1983	Variance
Yellow-billed Cuckoo																
n=20	n=14	n=6	n=8	n=124	n=30	n=13	n=77	n=49	n=76							
5	0.60 (0.41, 0.76)	0.36 (0.18, 0.58)	0.33 (0.11, 0.68)	0.45 (0.016)	0.49 (0.42, 0.57)	0.40 (0.27, 0.55)	0.69 (0.46, 0.86)	0.53 (0.022)	0.49 (0.40, 0.59)	0.53 (0.41, 0.64)	0.41 (0.32, 0.50)	0.48 (0.004)				
10	0.70 (0.51, 0.84)	0.57 (0.35, 0.76)	0.50 (0.21, 0.79)	0.63 (0.013)	0.69 (0.62, 0.76)	0.63 (0.48, 0.76)	0.85 (0.61, 0.95)	0.72 (0.012)	0.75 (0.66, 0.83)	0.61 (0.49, 0.72)	0.63 (0.54, 0.72)	0.67 (0.006)				
15	0.80 (0.61, 0.91)	0.71 (0.49, 0.87)	0.67 (0.32, 0.89)	0.76 (0.009)	0.82 (0.76, 0.87)	0.77 (0.62, 0.87)	1.00 (1.0, 1.0)	0.86 (0.015)	0.86 (0.78, 0.91)	0.82 (0.71, 0.89)	0.74 (0.65, 0.81)	0.80 (0.004)				
20	0.95 (0.78, 0.99)	0.79 (0.56, 0.91)	1.00 (1.0, 1.0)	0.93 (0.010)	0.93 (0.88, 0.96)	0.93 (0.81, 0.98)	1.00 (1.0, 1.0)	0.95 (0.002)	0.96 (0.90, 0.98)	0.88 (0.78, 0.94)	0.87 (0.79, 0.92)	0.90 (0.003)				
Great Crested Flycatcher																
n=56	n=28	n=12	n=17	n=139	n=38	n=21	n=42	n=36	n=75							
5	0.54 (0.43, 0.64)	0.21 (0.11, 0.37)	0.75 (0.50, 0.90)	0.55 (0.059)	0.64 (0.57, 0.70)	0.45 (0.32, 0.58)	0.62 (0.44, 0.77)	0.57 (0.011)	0.62 (0.49, 0.73)	0.61 (0.47, 0.73)	0.41 (0.32, 0.51)	0.55 (0.014)				
10	0.75 (0.64, 0.83)	0.54 (0.38, 0.68)	0.83 (0.58, 0.95)	0.75 (0.023)	0.73 (0.67, 0.79)	0.63 (0.50, 0.75)	0.76 (0.58, 0.88)	0.71 (0.005)	0.69 (0.56, 0.79)	0.83 (0.71, 0.91)	0.55 (0.45, 0.64)	0.69 (0.021)				
15	0.84 (0.74, 0.90)	0.68 (0.52, 0.80)	0.83 (0.58, 0.95)	0.82 (0.012)	0.85 (0.79, 0.89)	0.84 (0.72, 0.92)	0.90 (0.74, 0.97)	0.87 (0.001)	0.83 (0.72, 0.91)	0.97 (0.87, 0.99)	0.73 (0.64, 0.81)	0.85 (0.014)				
20	0.95 (0.87, 0.98)	0.89 (0.75, 0.96)	1.00 (1.0, 1.0)	0.94 (0.002)	0.91 (0.85, 0.94)	0.95 (0.84, 0.98)	0.95 (0.79, 0.99)	0.94 (0.001)	0.88 (0.77, 0.94)	0.97 (0.87, 0.99)	0.91 (0.83, 0.95)	0.92 (0.002)				
Acadian Flycatcher																
n=12	n=12	n=12	n=19	n=55	n=64	n=17	n=50	n=30	n=55							
5	0.92 (0.66, 0.98)	0.75 (0.50, 0.90)	0.75 (0.60, 0.90)	0.80 (0.006)	0.62 (0.51, 0.72)	0.78 (0.68, 0.85)	0.94 (0.75, 0.99)	0.78 (0.026)	0.68 (0.56, 0.78)	0.77 (0.62, 0.87)	0.76 (0.66, 0.84)	0.74 (0.002)				
10	1.00 (1.0, 1.0)	0.83 (0.58, 0.95)	0.75 (0.50, 0.90)	0.85 (0.006)	0.69 (0.58, 0.78)	0.86 (0.77, 0.92)	1.00 (1.0, 1.0)	0.83 (0.016)	0.78 (0.67, 0.86)	0.87 (0.73, 0.94)	0.87 (0.78, 0.93)	0.84 (0.003)				
15	1.0 (1.0, 1.0)	0.83 (0.58, 0.95)	0.83 (0.58, 0.95)	0.89 (0.006)	0.76 (0.66, 0.84)	0.91 (0.83, 0.95)	1.00 (1.0, 1.0)	0.83 (0.010)	0.94 (0.85, 0.98)	0.93 (0.81, 0.98)	0.95 (0.87, 0.98)	0.94 (<0.001)				
20	1.00 (1.0, 1.0)	0.83 (0.58, 0.95)	1.00 (1.0, 1.0)	0.93 (0.007)	0.82 (0.72, 0.89)	0.95 (0.88, 0.98)	1.00 (1.0, 1.0)	0.92 (0.009)	0.96 (0.88, 0.99)	0.97 (0.91, 0.99)	0.98 (0.91, 0.99)	0.97 (<0.001)				
Wood Thrush																
n=65	n=19	n=27	n=43	n=179	n=56	n=34	n=62	n=48	n=56							
5	0.54 (0.44, 0.64)	0.84 (0.65, 0.94)	0.85 (0.70, 0.93)	0.73 (0.022)	0.86 (0.81, 0.90)	0.77 (0.66, 0.85)	0.91 (0.79, 0.97)	0.85 (0.005)	0.84 (0.75, 0.90)	0.81 (0.70, 0.89)	0.70 (0.59, 0.79)	0.78 (0.006)				
10	0.69 (0.59, 0.78)	0.89 (0.71, 0.97)	0.89 (0.75, 0.96)	0.83 (0.009)	0.93 (0.89, 0.96)	0.95 (0.87, 0.98)	0.97 (0.86, 0.99)	0.95 (<0.001)	0.94 (0.86, 0.97)	0.88 (0.77, 0.93)	0.82 (0.72, 0.89)	0.88 (0.003)				
15	0.78 (0.69, 0.86)	1.00 (1.0, 1.0)	0.89 (0.75, 0.96)	0.90 (0.009)	0.99 (0.97, 1.0)	0.95 (0.87, 0.98)	1.00 (1.0, 1.0)	0.98 (<0.001)	0.95 (0.88, 0.98)	0.98 (0.90, 1.0)	0.91 (0.83, 0.96)	0.95 (0.001)				
20	0.89 (0.81, 0.94)	1.00 (1.0, 1.0)	0.93 (0.79, 0.98)	0.94 (0.002)	1.00 (1.0, 1.0)	0.98 (0.91, 1.0)	1.00 (1.0, 1.0)	0.99 (<0.001)	0.97 (0.90, 0.99)	0.98 (0.90, 1.0)	0.96 (0.89, 0.99)	0.97 (<0.001)				

Table 4---continued

Region 1										Region 2				Region 4				Mean and Variance	
1980	1981	1982	1983	Variance	1979	1980	1983	1983	Variance	1981	1982	1983	1983	1982	1983	1983	1983	Mean and Variance	Mean and Variance
Red-eyed Vireo																			
5	n=128 0.89 (0.85, 0.93)	n=105 0.90 (0.85, 0.94)	n=44 0.95 (0.86, 0.98)	n=56 0.84 (0.74, 0.90)	n=129 0.81 (0.75, 0.86)	n=75 0.83 (0.74, 0.89)	n=30 0.83 (0.69, 0.92)	n=30 0.83 (0.69, 0.92)	0.82 (0.74, 0.88)	n=79 0.89 (0.81, 0.93)	n=73 0.82 (0.74, 0.88)	n=115 0.76 (0.68, 0.82)	n=115 0.76 (0.68, 0.82)	n=73 0.82 (0.74, 0.88)	n=73 0.82 (0.74, 0.88)	n=73 0.82 (0.74, 0.88)	n=73 0.82 (0.74, 0.88)	0.82 (0.004)	0.82 (0.004)
10	0.98 (0.94, 0.99)	0.94 (0.89, 0.97)	0.97 (0.89, 1.0)	0.89 (0.80, 0.94)	0.92 (0.87, 0.95)	0.87 (0.79, 0.92)	0.90 (0.77, 0.96)	0.90 (0.77, 0.96)	0.89 (0.81, 0.93)	0.92 (0.86, 0.96)	0.90 (0.83, 0.95)	0.83 (0.76, 0.88)	0.83 (0.76, 0.88)	0.90 (0.83, 0.95)	0.90 (0.83, 0.95)	0.90 (0.83, 0.95)	0.90 (0.83, 0.95)	0.88 (0.003)	0.88 (0.003)
15	0.99 (0.96, 1.0)	0.98 (0.94, 0.99)	1.00 (1.0, 1.0)	0.96 (0.89, 0.99)	0.95 (0.91, 0.98)	0.95 (0.88, 0.98)	0.97 (0.84, 0.99)	0.97 (0.84, 0.99)	0.96 (0.90, 0.98)	0.99 (0.94, 1.0)	0.94 (0.88, 0.98)	0.90 (0.85, 0.94)	0.90 (0.85, 0.94)	0.94 (0.88, 0.98)	0.94 (0.88, 0.98)	0.94 (0.88, 0.98)	0.94 (0.88, 0.98)	0.95 (0.002)	0.95 (0.002)
20	1.00 (1.0, 1.0)	0.99 (0.95, 1.0)	1.00 (1.0, 1.0)	0.98 (0.91, 1.0)	0.97 (0.93, 0.99)	0.96 (0.90, 0.98)	1.00 (1.0, 1.0)	1.00 (1.0, 1.0)	0.98 (0.90, 0.98)	0.99 (0.94, 1.0)	0.96 (0.90, 0.98)	0.97 (0.92, 0.98)	0.97 (0.92, 0.98)	0.96 (0.90, 0.98)	0.96 (0.90, 0.98)	0.96 (0.90, 0.98)	0.96 (0.90, 0.98)	0.97 (0.001)	0.97 (0.001)
Ovenbird																			
5	n=45 0.80 (0.68, 0.88)	n=44 0.73 (0.60, 0.82)	n=10 0.60 (0.34, 0.81)	n=9 0.56 (0.29, 0.79)	n=19 0.53 (0.34, 0.70)	n=63 0.87 (0.79, 0.93)	n=83 0.82 (0.55, 0.94)	n=83 0.82 (0.55, 0.94)	0.74 (0.034)	n=72 0.78 (0.69, 0.85)	n=74 0.86 (0.79, 0.92)	n=117 0.84 (0.77, 0.88)	n=117 0.84 (0.77, 0.88)	n=74 0.86 (0.79, 0.92)	n=74 0.86 (0.79, 0.92)	n=74 0.86 (0.79, 0.92)	n=74 0.86 (0.79, 0.92)	0.83 (0.002)	0.83 (0.002)
10	0.93 (0.84, 0.97)	0.86 (0.75, 0.93)	0.80 (0.52, 0.94)	0.78 (0.48, 0.93)	0.79 (0.60, 0.90)	0.94 (0.86, 0.97)	0.91 (0.64, 0.98)	0.91 (0.64, 0.98)	0.88 (0.005)	0.89 (0.81, 0.94)	0.89 (0.82, 0.94)	0.92 (0.87, 0.96)	0.92 (0.87, 0.96)	0.89 (0.82, 0.94)	0.89 (0.82, 0.94)	0.89 (0.82, 0.94)	0.89 (0.82, 0.94)	0.90 (0.001)	0.90 (0.001)
15	0.96 (0.87, 0.99)	0.91 (0.81, 0.96)	0.90 (0.61, 0.98)	1.00 (1.0, 1.0)	0.90 (0.71, 0.97)	0.95 (0.88, 0.98)	1.00 (1.0, 1.0)	1.00 (1.0, 1.0)	0.94 (0.002)	0.96 (0.90, 0.98)	0.95 (0.88, 0.98)	0.97 (0.92, 0.98)	0.97 (0.92, 0.98)	0.95 (0.88, 0.98)	0.95 (0.88, 0.98)	0.95 (0.88, 0.98)	0.95 (0.88, 0.98)	0.96 (0.001)	0.96 (0.001)
20	0.96 (0.87, 0.99)	0.93 (0.84, 0.97)	1.00 (1.0, 1.0)	1.00 (1.0, 1.0)	0.90 (0.71, 0.97)	0.97 (0.90, 0.99)	1.00 (1.0, 1.0)	1.00 (1.0, 1.0)	0.97 (0.90, 0.98)	0.99 (0.93, 0.99)	1.00 (1.0, 1.0)	0.99 (0.96, 1.0)	0.99 (0.96, 1.0)	1.00 (1.0, 1.0)	1.00 (1.0, 1.0)	1.00 (1.0, 1.0)	1.00 (1.0, 1.0)	0.99 (0.001)	0.99 (0.001)

Table 5--The average percentage difference in frequency of occurrence simulated assuming probability of species' detection varies, but species' occurrence at points is constant. Changes in frequency of occurrence result solely from variation in species' detection probabilities.

Species	Minutes	Number of points Where Species Occurred			
		100		200	
		1 Visit	2 Visits	1 Visit	2 Visits
Yellow-billed Cuckoo					
Region 1	5	32.2	33.5	36.2	30.3
	10	26.1	13.4	23.0	13.0
	15	14.4	6.9	15.7	6.6
	20	11.2	4.5	12.7	3.5
Region 2	5	42.5	23.8	39.5	23.9
	10	18.5	8.8	17.4	8.2
	15	16.5	5.4	17.3	6.2
	20	5.2	0.9	4.8	0.6
Region 4	5	22.9	11.2	22.5	11.4
	10	16.0	7.7	15.3	7.0
	15	9.4	4.3	8.5	3.6
	20	8.5	1.5	7.3	1.7
Great Crested Flycatcher					
Region 1	5	76.0	54.6	72.5	44.3
	10	28.4	12.0	26.6	11.0
	15	17.4	5.8	14.1	5.3
	20	5.2	0.9	5.5	0.8
Region 2	5	24.8	14.8	26.0	15.4
	10	14.2	6.1	10.5	6.5
	15	5.9	1.9	5.9	1.5
	20	4.5	0.8	3.7	0.5
Region 4	5	28.2	16.0	25.8	19.2
	10	25.3	14.4	28.3	13.0
	15	15.2	5.8	14.8	5.3
	20	7.3	1.1	6.3	1.1
Acadian Flycatcher					
Region 1	5	12.6	4.4	15.4	4.9
	10	10.9	3.7	9.1	3.1
	15	11.3	2.1	10.3	2.8
	20	9.7	2.1	8.2	1.4
Region 2	5	29.1	11.4	28.2	10.9
	10	19.0	5.0	24.5	6.7
	15	15.8	4.7	20.0	4.5
	20	1.2	3.0	11.8	3.3
Region 4	5	9.9	4.8	8.3	3.3
	10	9.0	2.7	7.9	2.3
	15	3.1	0.6	1.9	0.4
	20	2.6	0.2	2.0	0.2
Wood Thrush					
Region 1	5	23.1	13.7	25.6	13.1
	10	13.0	5.6	13.6	4.0
	15	10.9	3.0	11.3	2.7
	20	5.4	1.0	5.6	0.9
Region 2	5	10.1	2.7	10.6	3.3
	10	3.5	0.5	3.9	0.5
	15	2.5	0.2	3.1	0.2
	20	1.0	0.0	0.9	0.1
Region 4	5	12.6	4.7	11.2	4.1
	10	9.3	2.2	7.6	1.5
	15	4.6	0.8	4.3	0.6
	20	2.2	0.2	1.4	0.2

continued

Table 5--continued

Species	Minutes	Number of Points Where Species Occurred			
		100		200	
		1 Visit	2 Visits	1 Visit	2 Visits
Red-eyed Vireo					
Region 1	5	8.1	1.5	7.8	1.2
	10	5.8	0.8	4.2	0.5
	15	2.4	0.1	1.6	0.1
	20	0.9	0.0	1.0	0.0
Region 2	5	5.5	2.2	3.6	1.3
	10	5.0	1.3	3.8	1.2
	15	2.8	0.2	2.2	0.3
	20	2.9	0.2	2.9	0.2
Region 4	5	11.3	4.0	8.5	3.7
	10	7.3	2.2	8.0	1.4
	15	5.0	0.8	5.2	0.6
	20	2.8	0.2	2.2	0.0
Ovenbird					
Region 1	5	20.6	12.5	22.9	11.0
	10	9.9	3.2	10.8	3.0
	15	6.8	0.8	5.8	1.0
	20	3.5	0.3	4.5	0.4
Region 2	5	40.2	15.4	29.3	14.7
	10	10.2	2.7	11.4	3.3
	15	7.1	0.8	7.6	0.9
	20	5.8	1.0	5.2	0.8
Region 4	5	10.2	2.7	7.2	2.2
	10	4.7	1.0	3.7	0.9
	15	2.7	0.2	2.1	0.3
	20	0.8	0.0	0.8	0.0

