

Detectability of Forest Birds from Stationary Points in Northern Wisconsin¹

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Abstract: Estimation of avian densities from point counts requires information about the distance at which birds can be detected by the observer. Detection distances also are important for designing the spacing of point counts in a regional sampling scheme. We examined the relationship between distance and detectability for forest songbirds in northern Wisconsin. Like previous investigators, we found that some birds can be heard from much greater distances than others. Within the same species, some individuals (or the same individual under different circumstances) can be heard from greater distances than others. In general, this within-site variation in detectability is similar to variation in detectability among individuals in different forest types. Knowledge about the relationship between distance and detectability can be used to approximate the area sampled from a stationary point. This information can then be used to estimate the density of vocalizing birds. Even under ideal field conditions with accurately measured distances, detectability does not follow a simple threshold relationship. On the basis of our empirical data, we use a statistical probit analysis to describe the attenuation of detection with distance; the resulting sigmoidal function can be used to approximate the effective sampling area. Complications arise because individual birds become increasingly difficult to distinguish from conspecifics at greater distances from the observer. Coupled with variation caused by habitat structure, wind conditions, observer bias, and other factors, we conclude that data from point counts can give only a crude picture of avian density. Nevertheless, such estimates might be the best available, and the costs or ambiguities associated with alternative procedures might outweigh the disadvantages of the point count method.

Point counts are attractive for avian population monitoring programs because they are methodologically straightforward and permit sampling of numerous geographic sites. Results from unlimited-radius point counts are generally accepted as valid indices of abundance for a single species under some circumstances (Blondel and others 1981), but between-species comparisons of point counts are complicated by species-specific differences in detectability. Even within-species comparisons are based on the untested assumption that detectability is consistent among different sites. Of course, virtually any method for sampling bird populations is burdened with weaknesses (Ralph and Scott 1981). Despite its shortcomings, the point count method is probably the least subjective of today's widely used procedures. Unlimited-radius point counts are probably the simplest of all approaches because, unlike the variable-radius point count method (Reynolds and others 1980) or the fixed-radius method (Gates, in these Proceedings), observers do not need to estimate the distance of each bird from the observer. Interpretations of unlimited-radius point counts, on the other hand, are more sensitive to differences in detectability

among individuals of the same or different species.

In this paper we provide an objective analysis of the relationship between distance and detectability of forest songbirds in northern Wisconsin. We focus particular attention on the maximum distance from which an observer can detect a singing bird. This distance dictates the area covered by an unlimited-radius count and has obvious implications for designing and interpreting point count procedures. We also consider how empirically derived relationships between detectability and distance might be used in conjunction with point count data to generate estimates of relative (or perhaps absolute) avian abundance.

Emlen and DeJong (1981) pointed out that detection of bird vocalizations is a threshold phenomenon—a bird is either heard or it is not heard. If detectability thresholds (the maximum distances from which birds can be heard) are species-specific and reasonably consistent among the habitats of interest, then the area covered by an unlimited-radius point count theoretically can be determined empirically (area = πD_t^2 where D_t = the detectability threshold) (Reynolds and others 1980). The number of vocalizing individuals detected within this area then can be used to calculate bird density. Estimates of detectability thresholds also may provide insight into other issues considered in this volume, notably the ideal distance between census points needed to assure independence of sample points.

Methods

Field work was carried out in second-growth northern hardwood forests approximately 10 km southwest of Wabeno, Wisconsin, in the heart of the Nicolet National Forest. Data were collected mainly from an extensive forest area dominated by sugar maple (*Acer saccharum*), aspen (*Populus tremuloides*), yellow birch (*Betula lutea*), and several other tree species. The site was logged intensively before the 1930's, and trees have been selectively removed since that time. Canopy cover is approximately 80 percent to 85 percent based on field measurements with a forest densimeter (Schneider 1992). Average tree height is approximately 20 m to 25 m. The understory consists mainly of irregular patches of elderberry (*Sambucus pubens*), gooseberry (*Ribes* sp.), and other shrubs (especially *Rubus* sp.). Additional data were collected at two sites dominated by aspen (*Populus tremuloides*) and two lowland sites dominated by northern white cedar (*Thuja occidentalis*).

A primary site of 18 ha (600 m by 300 m) was marked with a grid of color-coded forestry flagging at 50-m intervals. Distances between flags were measured carefully with a compass and meter tape. Positions of birds and observers were mapped with reference to these color-coded grid points. Once a bird was located by one observer, a second observer in communication via a two-way radio would take a marked

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grid position. The second observer then recorded whether the target bird was audible from his or her position. Beginning at a mutually established time, the two observers would record the precise moment of up to five consecutive songs. Before the observation period, digital watches were synchronized to the second, permitting comparisons of the independent records. If the bird was still audible, the second observer moved to a position farther (usually 12.5 m to 25 m) away from the bird. As long as the bird remained stationary, this procedure was repeated until the bird could no longer be heard by the second observer. Exact distances between recorded positions (given as angles and distances from grid points) were later calculated using a computer program.

Observations were recorded from sunrise until approximately noon, generally under calm conditions (wind 0 to 3 mi/h). Windspeed and cloud cover were recorded at the beginning of the observation period, but these variables, as well as differences among observers, will not be considered in this paper. Four observers took part in the analysis by locating singing birds, but the bird detections reported here were made exclusively by R.W. Howe and A.T. Wolf.

Results

We recorded detectability of vocalizations at various distances for individuals of 23 bird species. The maximum detection distance was recorded for American Crow (*Corvus brachyrhynchos*) which, on one occasion, could be heard clearly from 725 m. White-throated Sparrows (*Zonotrichia albicollis*) were heard at every distance tested, with a maximum distance of 287 m. Indigo Buntings (*Passerina cyanea*) could be heard from 392 m along a road corridor, and other individuals of this species (six of eight birds tested) were heard at distances exceeding 300 m. At the other extreme, Brown Creepers (*Certhia americana*), White-breasted Nuthatches (*Sitta carolinensis*), and Golden-crowned Kinglets (*Regulus satrapa*) could not be heard beyond 100 m. Typically, however, forest songbirds in northern Wisconsin become inaudible between approximately 125 and 250 m. Among forest interior species, Hermit Thrush (*Catharus guttatus*) and Veery (*Catharus fuscescens*) could be detected for the greatest distances (table 1). We were able to detect 71 percent of Hermit Thrush songs between 200 m to 275 m ($n = 48$ songs, 11 individuals). By comparison, only 7.4 percent of Ovenbird (*Seiurus aurocapillus*) songs could be detected in this range of distances.

Table 1—Maximum and minimum distances (detectability distances) at which singing birds became inaudible to an observer in the Nicolet National Forest. Species with detection distances that extended well beyond our sample distances (American Crow, Indigo Bunting, and White-throated Sparrow) and species with records representing only a few distances (Eastern Wood-Pewee, and Brown Creeper) are not included

Species	Detection distance		D_{50}^c (s.d.) ^d		Total	
	Minimum ^a	Maximum ^b			Records ^e	
Veery	180	208	272	(90)	13	(42)
Hermit Thrush	179	271	240	(88)	33	(104)
Ovenbird	168	206	182	(35)	89	(298)
Winter Wren	156	236	170	(43)	20	(55)
Nashville Warbler	158	222	165	(220)	17	(41)
Red-eyed Vireo	78	188	164	(100)	27	(27)
Least Flycatcher	92	193	163	(83)	50	(50)
Black-throated Green Warbler	122	217	151	(57)	20	(49)
Black-throated Blue Warbler	121	153	140	(26)	16	(40)
Chestnut-sided Warbler	83	126	129	(47)	10	(18)
Mourning Warbler	109	133	125	(52)	24	(66)
Black-capped Chickadee	-	125	100	(1)	10	(13)
Black-and-White Warbler	98	104	98	(12)	13	(14)
Golden-crowned Kinglet	-	95	91	(3)	11	(19)
White-breasted Nuthatch	-	72	76	(1)	4	(8)

^aMinimum = the shortest distance from which an observer failed to hear an individual bird.

^bMaximum = the longest distance from which an observer was able to detect an individual.

^c D_{50} is the midpoint of a best-fit cumulative normal distribution describing the attenuation of detection with distance. At this distance, the probability of hearing a bird is 50 percent.

^ds.d. = standard deviation (σ) of the fitted normal distribution; a low value reflects a steeper decline of detectability with distance.

^eTotal records indicate the total number of birds for which distances were measured. Total number of songs evaluated by observers is indicated in parentheses.

We focus particular attention on the Ovenbird, by far the most common species in our study area. Ovenbirds could be heard from a maximum distance of 206 m, yet even at 67 m individual songs were occasionally overlooked or confused with those of nearby individuals. As a result of unidentified factors (presumably topography, weather, individual differences among birds, etc.), bird song detectability does not follow a clear threshold function. We found a gradual decline in our ability to detect vocalizations as we moved farther away from these birds (*fig. 1*). Other species show a similar relationship between distance and detectability although the detection distances vary (*table 1*). Bird songs within a certain range of distances are audible during some trials but inaudible during others. For example, an Indigo Bunting singing from a tree 256 m from the observer (R.W. Howe) could be heard clearly, but when it flew into dense shrubs (*Rubus* sp.) beneath the tree its songs became inaudible to the distant observer. An Ovenbird could be heard from 194 m in one part of the forest, but on the same day at the same site another individual was inaudible from a distance of 174 m.

Note that detection of even one song during a sampling period would be enough to include the bird in a stationary point count. A typical Ovenbird will sing approximately three

times during a single minute (average time between songs, $t_s = 20.89$, ($\sigma = 8.23$, $n = 140$), while many other species sing even more frequently (Black-throated Green Warbler (*Dendroica virens*) $t_s = 8.5$, $\sigma = 1.64$, $n = 24$; Hermit Thrush $t_s = 5.89$, $\sigma = 1.67$, $n = 55$; Indigo Bunting $t_s = 12.3$, $\sigma = 2.45$, $n = 20$; Mourning Warbler (*Oporornis philadelphia*) $t_s = 13.65$, $\sigma = 3.89$, $n = 31$; Winter Wren (*Troglodytes troglodytes*) $t_s = 16.03$, $\sigma = 4.29$, $n = 34$).

Clearly, detection distances are not adequately expressed by a single threshold number; instead, some other descriptor or function is needed to describe the area sampled by a stationary point count. Using field data like ours, plots can be generated showing the attenuation of detectability with distance (*fig. 1*). One can then superimpose or fit a theoretical function to describe the relationship between distance and detectability. Here we use probit analysis (Finney 1971), a procedure that has been used to describe the relationship between dosage and response to toxins, loss of seed viability in plants (Wilson and others 1989), spread of disease in oaks (Bruhn and others 1991), and other applications where the probability of some event is related to a cumulative form of a standard distribution. On the basis of the sigmoidal shape of our detectability distance plots, we assume that the probability

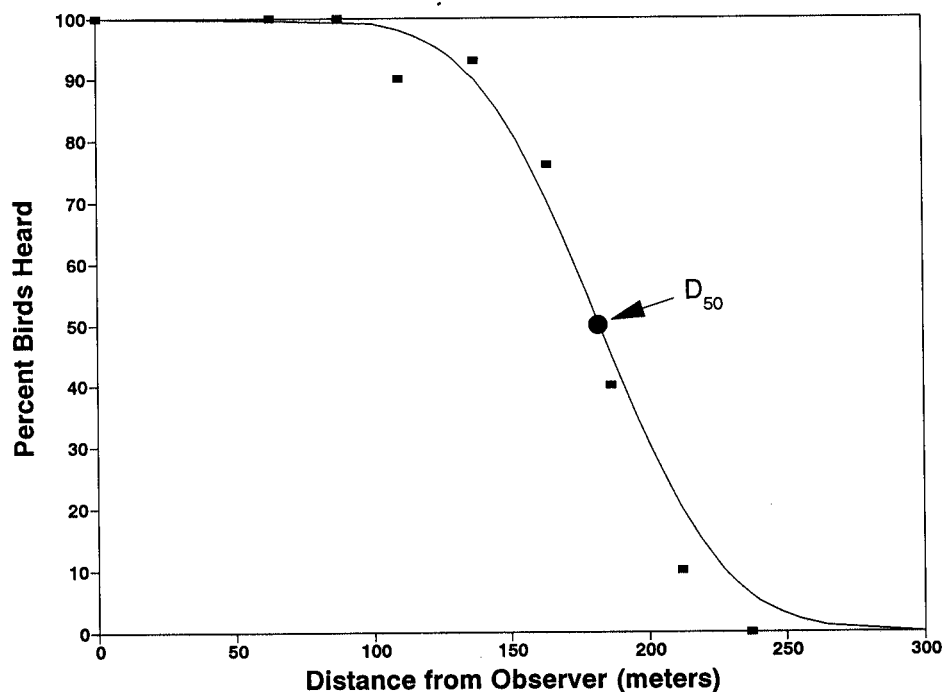


Figure 1—Relationship between song detectability and distance from observer for the Ovenbird in northern Wisconsin. Line indicates the inverse of the best-fit cumulative normal distribution as determined by statistical probit analysis. Solid squares (■) indicate pooled data for 25-m distance categories ($n > 10$ birds for all categories between 100 m to 200 m; $n = 3-7$ for others). D_{50} indicates the distance where one-half of the birds of a given species are audible.

of hearing a bird declines with distance according to the inverse of a cumulative normal distribution (fig. 1). Parameters of the distribution (μ and σ) were estimated using an algorithm in the SAS statistical software program. A critical value, D_{50} (an estimate of μ), indicates the distance where one-half of the birds of a given species are audible. D_{50} marks a useful definition of sampling radius (and hence, area) insofar as the probability of hearing a bird is the same as the probability of missing a bird. Because birds sing more than once and undoubtedly move during a given sampling period, D_{50} must be recognized as a somewhat arbitrary definition of sampling radius. Values of D_{50} vary according to relative detectability; species with high values can be heard for greater distances from a sampling point than can species with a low D_{50} . Note that these curves are similar to those derived empirically in variable circular-plot sampling (Reynolds and others 1980).

Probably as important as the ability to detect a given species is the ability to distinguish one individual from another. We found that this became increasingly difficult as an observer moved farther away from a bird. In many cases, the observer's failure to record 100 percent of the target bird's songs was caused by confusion with other singing birds. This was particularly true for Ovenbirds and Red-eyed Vireos (*Vireo olivaceus*), which were abundant and highly vocal in our study area. Confusion of individual songs occurred even at relatively short distances (<100 m), and at distances of 150 m or more, separation of nearby individuals was nearly impossible.

We noted only slight differences in detectability for the same species among different habitats. Hermit Thrushes, for example, were detectable from a maximum of 271 m in the aspen sites compared with 242 m in the swamp conifers. In only one instance did we find a habitat-related difference in detectability: Ovenbirds were significantly more detectable in hardwoods (71 percent, $n = 87$) than in aspens (55 percent, $n = 29$) at a distance of 150 m to 175 m ($P < 0.05$, Chi-square contingency test). In all other cases either the species was effectively restricted to a single habitat type or differences between habitats were not statistically significant ($P > 0.05$).

Discussion

The maximum detection distances recorded during our study generally agree with those reported by Emlen and DeJong (1981). For example, they found among 11 species of deciduous forest birds that Wood Thrush could be heard from the greatest distance. Similarly, we recorded long detection distances for Hermit Thrush, a species whose song is very similar to that of the Wood Thrush. Although both sample sizes are rather small, together our results show that many songbirds in forests of Northeastern America can be detected from distances exceeding 150 m; certain species (e.g., Veery, Winter Wren) can be heard from 200 m or more, and birds like Indigo Buntings and White-throated Sparrows are audible beyond 250 m to 300 m. Given this fact, two separate point counts would need to be more than 400 m apart to assure that no individual birds would be recorded in both counts. Even this distance would be insufficient if birds near the mutual

boundary move from one sampling area to the other during the count period.

Estimation of avian densities from point counts is complicated by several problems. Like Emlen and DeJong (1981), our results show significant variations in detection distances even among records from the same species and by the same observer. Such variations mean that calculations based on a standard detection radius will lead to overestimates or underestimates of population densities. Suppose, for example, we used a value of 180 m as the standard detection radius for Ovenbirds. If the actual detection distance at a given site due to topography or individual differences in song quality was actually 200 m, then the area covered by the point count would be 12.56 ha (assuming a 200-m radius) instead of 10.18 ha (assuming a 180-m radius). Individual counts would overestimate actual densities by approximately 23 percent. If the actual detection radius was 160 m, an area of only 8.04 ha would be covered, leading to underestimates of 21 percent.

Our detection distances tended to be slightly but consistently greater than those reported by Emlen and DeJong (1981). We suspect that this might be due to the shorter and more open forests of the Nicolet National Forest compared with the taller forest studied by Emlen and DeJong. Within the Nicolet National Forest, however, we found little evidence of differences in detection distances among different forest types. Of course, factors such as the perch height and orientation of the bird, hearing ability of the observer, wind conditions, individual variation in song intensity, and vegetation structure all can be expected to affect detection radii and their applications. The effects of these factors can be minimized if counts are limited to calm weather and to habitats that resemble the areas from which detectability radii are derived. Longer census durations improve the probability that a singing bird will be detected, but since birds typically offer three or more cues during a single minute, 5-minute counts would seem to offer adequate opportunity to detect a bird within the maximum detection radius.

Our analysis revealed an unanticipated difficulty with the estimation of density from point counts. As the distance between the observer and a singing bird increases, the bird's songs become increasingly difficult to distinguish from the songs of neighboring individuals. This effect typically occurs well before the song itself becomes inaudible. For example, two birds singing from perches approximately 20 m apart would be separated by an angle of 23° from an observer 50 m away. At 100 m, the same birds would be separated by an angle of only 11.5° from the observer's perspective. The closer birds would be much easier to distinguish from each other. Likewise, two birds that are aligned in approximately the same direction, but at different distances from an observer, will be more difficult to distinguish from one another the farther they (as a pair) are away from the observer. The net result of both circumstances is the same: unlimited-radius point counts will tend to underestimate the number of individuals within the detection range of a species because certain pairs or even trios far from the observer will be counted as a single individual. This problem will be most severe for locally abundant species and might be insignificant for

species that occur in low densities. In our study area, 88 percent of the species recorded during 10-minute point counts ($n = 641$) were represented by only one or two individuals (Howe and others, in this volume).

A further complication arises when birds from adjacent areas move into detection range during the count period. Inadvertently including them will lead to overestimates of abundance, because corresponding birds that move out of the detection range obviously are not subtracted from the total. This effect might be partly compensated by birds moving out of the detection range before they are detected. Fixed-radius (e.g., 50-m) point counts are more vulnerable to these boundary effects than are unlimited-radius (e.g., much greater than 50-m) point counts because smaller areas have higher ratios of perimeter to area. Based on considerations discussed earlier, however, movements of birds into the count area are more likely to be recognized close to the observer (i.e., <50-m), at least partly mitigating this boundary effect. Whatever the balance between these factors, point counts should be as short in duration as possible (e.g., 5 minutes or less) to minimize undetected movements of birds into or out of the count area.

Estimation of density from point counts requires either a fixed-sampling radius or some empirically derived function that describes the relationship between bird detectability and distance (Emlen and DeJong 1981, Ramsey and Scott 1981, Reynolds and others 1980, Scott and others 1981). We have

attempted to systematically describe this relationship for forest birds in northern Wisconsin. Our results show that the relationship is complicated. In spite of inherent (and probably unavoidable) difficulties, crude estimates of detection radii such as those presented here are more objective than the *ad hoc* estimates described by Reynolds and others (1980) and related studies. Estimates of densities using systematically derived detection radii such as the D_{50} from probit analysis have practical value insofar as they are far better than no quantitative estimates at all, and they provide standardized comparisons between point counts within the same habitat type.

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