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LATERAL DETECTABILITY PROFILES FOR LINE TRANSECT BIRD CENSUSES: SOME PROBLEMS AND AN ALTERNATIVE

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ABSTRACT.—We censused all land birds along a 1-km transect route through a riparian bottomland site in western Montana. Four censuses were conducted by one observer and four were conducted by two observers working together. The addition of a second observer: (1) increased the number of individuals detected for most of the bird species present; (2) increased the number of detections significantly more for rare than for common species; and (3) increased the number of detections significantly more at farther than at closer lateral distances. Considering the problems that exist with estimating true lateral detectability profiles, these results suggest that multiple observers might serve better as a method for dealing with detectability differences among species than a method involving the use of detectability profiles.

Reviews of methods for estimating the densities of land bird species (Kendeigh 1944, J. T. Emlen 1971, Dickson 1978, Shields 1979) all recognize the great utility of line transects. Despite the efficiency of such methods, the accuracy of the same methods is questionable. A major reason for inaccuracy stems from the fact that species differ in their conspicuousness. The proportion of individuals within a given transect width that is actually observed during a census differs among species, and is probably rarely 100% for any species (Järvinen 1978b).

In a seminal paper on census methods, J. T. Emlen (1971) addressed this problem of detectability differences among species and suggested that we record the lateral distance at which each individual is detected from the transect line. One can then plot the frequency of observations at various lateral distances and from this "detectability profile" determine the lateral distance at which detectability begins to decline for each species. The density of a given species is then based on the lateral width within which all individuals are assumed to be detected. We suspect that such detectability profiles are often inaccurate representations of the actual lateral detectabilities of many bird species because of the responses of birds to observers and because of the biased accumulation of detections that results from multiple use of a fixed transect route. In this paper we more clearly define these problems and investigate a possible alternative to the determination of lateral detectabilities.

Preston (1979) recently described how the number of individual birds detected increases with the number of observers, but he presented no data on whether the same proportionate increase occurs for all species and at all lateral distances from the transect line. If the bulk of additional observations comes from the greater lateral distances, or from the least conspicuous species, then additional observers would provide a simple method of minimizing the differences in detectability among species. In this paper "detectability" simply refers to the proportion of individuals of a given species that is likely to be detected within a given transect area. This usage is analogous to J. T. Emlen's (1971) "coefficient of detectability." Here we ask, "Do the additional observations that result from a second observer come disproportionately from inconspicuous species and/or from greater lateral distances?"

METHODS

We established a 1-km line transect in a heavily grazed riparian bottomland 8 km SW of Missoula, Montana (47°30′N, 114°6′W). The site was dominated by cottonwood (*Populus trichocarpa*) and ponderosa pine (*Pinus ponderosa*) in the overstory and by hawthorne (*Crataegus douglasii*), willow (*Salix alba*), dogwood (*Cornus canadensis*), snowberry (*Symphoricarpos albus*), and rose (*Rosa* sp.) in the understory.

We conducted eight censuses—four 2-observer censuses and four 1-observer censuses (each of us conducted two). In 2-observer censuses we generally walked within 5 m of one another and focused our attention in opposite directions. Since human voices seem to disturb birds little, if at all, we communicated vocally when a bird was detected to ensure that all detections were recorded and that no bird detected by both parties was recorded twice. All birds seen or heard were recorded by one of us and their lateral distances from the transect line were estimated with the aid of a "ranging-620" rangefinder. We conducted all censuses from 07:00–10:00 between 10 June and 1 July 1980, and alternated 1-observer censuses with 2-observer censuses to avoid biases that might be associated with time of season.

Singing males were recorded as a pair of birds and nonsinging individuals of the same species adjacent to such males were assumed to be mates and went un-

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TABLE 1

TOTAL DETECTIONS OF SPECIES BY LATERAL DISTANCE CATEGORIES AS RECORDED BY A SINGLE OBSERVER

Species	Lateral distance (m)									Total pairs
	0–5	5–10	10–15	15–20	20–25	25–30	30–40	40–60	>60	
Falco sparverius							1			1
Bonasa umbellus	1									1
Zenaida macroura	1	2			1		1	1		6
Megaceryle alcyon				1						1
Colaptes auratus	1	1	1	1			1			5
Melanerpes lewis		1								1
Sphyrapicus varius	1									1
Picoides pubescens		4	1							5
Tyrannus tyrannus	1	2		1	2	1	1	1		9
Empidonax traillii		2	2			2	1			7
Empidonax minimus			1							1
Contopus sordidulus	12	9	7	4	2	5	2			41
Pica pica		1								1
Parus atricapillus	1	1		1			1			4
Parus gambeli	1		1							2
Sitta carolinensis		2	2			1				5
Troglodytes aedon			1	2		1				4
Dumatella carolinensis	1		4	2	1		1			9
Turdus migratorius	9	8	5	5	2		3	1		33
Catharus fuscescens	1	2	2	3	3					11
Bombycilla cedrorum		1	1							2
Vireo solitarius			1	1			1			3
Vireo olivaceus	2	3	3	6	1	1	2			18
Vireo gilvus	1	4	5	2	2	1	2			17
Dendroica petechia	2	9	10	10	3	4	3			41
Dendroica coronata	1	2	1			1				5
Setophaga ruticilla	1	3	4	2	1	1	2			14
Icterus galbula		1	1					1		3
Molothrus ater	8	3	6	4	3	1	4			29
Piranga leudoviciana	1	1	1		1				1	5
Pheucticus melanocephalus		1		1	1	1		2		6
Melospiza melodia		1	1		2		1	1		6
Carduelis pinus	2									2
							Grand total			299
							Number of species			33

recorded. Nonsinging individuals observed away from the vicinity of singing males were recorded as single individuals unless there was evidence that they were paired (e.g., another nonsinging individual of the same species nearby, nest material in bill, and so forth).

Since all censuses were conducted within the same study plot, the generality of our results remains unknown.

RESULTS

The numbers of individuals of each species that were detected at various lateral distances for 1-observer and 2-observer censuses are given in Tables 1 and 2, respectively. Both the number of species and the number of individuals recorded were greater for the 2-observer censuses. Preston (1979) derived an empirical expectation from Lack's (1976) data that the number of birds observed ought to increase in proportion to the square root of the number of observers, but the increase recorded here (299 to 348) is less than expected (299 to 422) on that basis. We suspect that the less pronounced increase recorded here reflects differences in the habitat types involved. Lack (1976) worked in species-rich, tropical deciduous forests and it is not surprising that an additional observer might add proportionately more individuals there, where the species are generally more secretive and restricted in their vertical distributions (Lovejoy 1975).

To determine whether the difference in a species' abundance between 1- and 2-observer censuses was related to its commonness, we categorized a species as being uncommon if fewer than 3 pairs were recorded at any lateral distance after four 2-observer censuses. By this method, 13 species were categorized as "uncommon" and 25 species as "common." For

TABLE 2
TOTAL DETECTIONS OF SPECIES BY LATERAL DISTANCE CATEGORIES AS RECORDED BY TWO OBSERVERS

	Lateral distance (m)									
Species	0–5	5–10	10–15	15–20	20–25	25–30	30–40	40–60	>60	Total pairs
Falco sparverius							1		1	2
Bonasa umbellus	2									2
Zenaida macroura	1	1		1		1	1	2	2	9
Megaceryle alcyon									2	2
Colaptes auratus	1	2	1		1	1			2	8
Melanerpes lewis				1						1
Sphyrapicus varius			1							1
Picoides pubescens	2	1	1	2	1					7
Tyrannus tyrannus	2		1			1			2	6
Empidonax traillii	2	1				1	1	2		7
Empidonax minimus		1	1							2
Contopus sordidulus	9	7	7	7	5	3	8	2	1	49
Pica pica			1							1
Parus atricapillus		2	2			1		1		6
Parus gambeli	1		1							2
Sitta carolinensis	2		1				1	1		5
Troglodytes aedon			2			1	1	1		5
Dumatella carolinensis	2	1	1	1			1			6
Turdus migratorius	7	10	3	4		4	4	1		33
Catharus fuscescens				1	3	2	2		3	11
Bombycilla cedrorum	1	1		1			1			4
Vireo solitarius		1		1	1					3
Vireo olivaceus	1	5	3	2	3	1	2	1		18
Vireo gilvus	4	4	1	4	2	2	2	1		20
Dendroica petechia	3	5	8	10	3	4	4	2	4	43
Dendroica coronata		1			2					3
Seiurus noveboracensis								1		1
Oporornis tolmiei				1						1
Setophaga ruticilla	2	2	4	1	1	2	2			14
Icterus galba		2		1		1	1		1	6
Molothrus ater	9	4	3	4	3	4	6	7	2	42
Piranga leudoviciana	1	1	1		3		1			7
Pheucticus melanocephalus	1	1	1	1		2	1	2		9
Hesperiphona vespertina				1						1
Melospiza melodia			2		1		1			4
Carpodacus cassinii		1		1						2
Carduelis pinus	1			3						4
Carduelis tristis								1		1
							Grand Total			348
							Number of species			38

each species we then noted the percent change in abundance from 1- to 2-observer censuses. Any species that increased from zero observed had, of course, an infinite percent increase. Such increases from zero were conservatively labeled 100% if the increase was from 0 to 1, 200% if from 0 to 2, and so on.

Uncommon species showed an increase in numbers detected that was significantly greater than the increase recorded for common species (69.2 ± 48.0% vs. 22.5 ± 40.8%; approximation of t-test, $P < 0.05$, Sokal and Rohlf 1969). Thus, the increase in numbers of individuals detected with an additional observer is non-random; the additional detections come disproportionately from uncommon species.

We were also interested in whether the same proportionate increase in bird detections occurred at all lateral distances. The relationship between the number of detections and lateral distance category (<15 m, 15–30 m, >30 m) was significantly different between 1- and 2-observer censuses ($G = 10.51$, $P < 0.01$; Table 3); the increase in number of detections with two observers came disproportionately from the farthest lateral distance category. Continuing in this vein, we measured the direction and magnitude of change in detections from 1- to 2-ob-

TABLE 3
THE NUMBER OF DETECTIONS BY DISTANCE CATEGORIES FOR 1- AND 2-OBSERVER CENSUSES[a]

	Lateral distance		
	0–15 m	15–30 m	>30 m
1-observer censuses	173	91	35
2-observer censuses	154	108	86

[a] The data are significantly heterogeneous (G-test, $P < 0.01$).

TABLE 4
THE CHANGE IN NUMBER OF SPECIES WITH AN ADDITIONAL OBSERVER

	Lateral distance		
	<15 m	15–30 m	>30 m
Decrease	14	8	2
No change	16	13	17
Increase	8	17	19

server censuses for each species within each of the three lateral distance categories. The numbers of species that showed a decrease, no change, or an increase in number of detections upon the addition of a second observer are presented in Table 4. The direction of change is not statistically significantly related to lateral distance ($G = 7.9$, $P < 0.1$), but the trend for most species was for the number of detections to decrease or remain the same at close lateral distances, and remain the same or increase at farther lateral distances. The mean magnitudes of change in numbers of individuals detected with the addition of a second observer were +6.1%, +39.9%, and +79.8%, for the <15 m, 15–30 m, and >30 m categories, respectively.

DISCUSSION

Application of the variable-width strip transect method requires delineation of a "profile" of the detectability of each species—a plot of the number of observations of a given bird species against the lateral distance at which each individual is sighted from the transect line. At least two factors lead us to suspect that such profiles are often unrelated to the actual detectability of their respective species. The first involves poor sample sizes that accrue for the majority of species seen; the inflection point in their detectability profile may not even be recognizable. A look at any of the species in Table 1 with fewer than 30 observations (92% of the species) will illustrate the difficulty of pinpointing the lateral distance at which detectability begins to decline.

Secondly, when detectability profiles *can* be clearly delineated, they may be artifacts of the behavior of birds (Fig. 1). For example, some bird species may move toward or away from a moving observer or, as was often the case with vireos in our study, they may sing and be detected easily only when away from the observer. In other instances, the positions of individuals that are detected on each transect run may be fixed relative to a permanently positioned transect line. By way of example, consider the Willow Flycatcher (*Empidonax traillii*) (Table 1 or 2). We ordinarily observed two singing males, one always about 10 m from the transect and another always atop the same willow, about 30 m from the transect line. The lateral distances that we recorded for this species were unrelated to the species' lateral detectability but, instead, reflected where their song posts happened to be positioned relative to the transect line. The House Wren (*Troglodytes aedon*) observations are similarly biased. This problem is especially acute when sample sizes are low and the locations of singing individuals are not likely to change from day to day.

For these reasons we looked for an alternative to the use of detectability profiles. We expected that utilization of an additional observer during censuses would increase the number of birds observed (Lack 1976, Preston 1979), but wished to determine whether each species and each lateral distance category revealed the same proportionate increase in numbers observed. If the numbers of detections of the conspicuous species do not increase much by an additional observer but those of the inconspicuous species do, then additional observers would provide a simple method of minimizing the difference in detectability among species. Moreover, if the bulk of new observations are located at the greater lateral distances, then not only would the detectability differences among species be minimized, but the detectability of all species might be raised to an acceptable level within a belt transect that is wide enough to generate reasonable sample sizes.

In our study the addition of a second observer produced three results that are of interest:

(1) There was an increase in the number of individuals detected for most (61%) of the bird species present. Some species (29%) revealed no change in the number of detections, presumably because they are conspicuous and all the individuals that are present can be readily detected by a single observer. Four species (10%) actually revealed a decrease in the number of detections, which is not unexpected since we are dealing with mobile animals whose true abundances may vary from day to day.

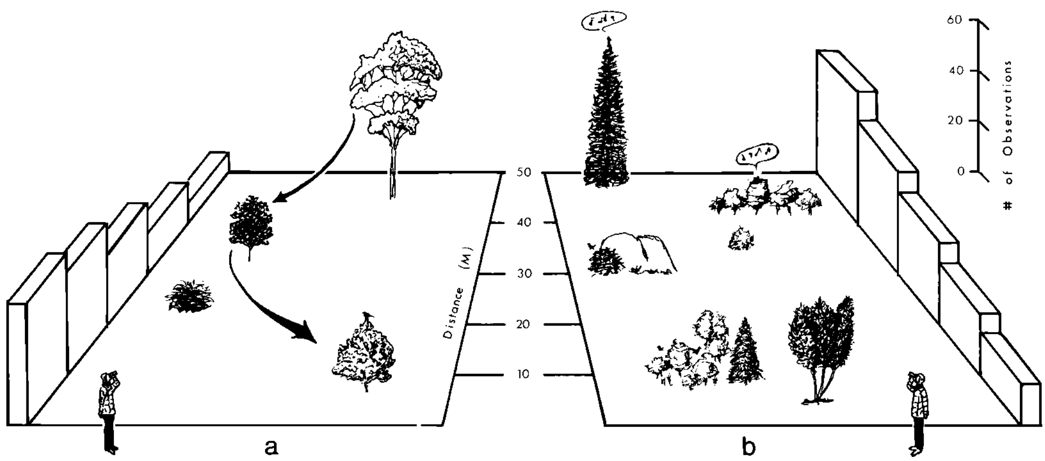

FIGURE 1. Two lateral detectability profiles that have been biased by the behavior of birds are represented by the block histograms. In (**a**), individuals of some species have been attracted to the observer, which would produce greatly inflated density estimates based on such a profile. In (**b**), individuals of other species are actually more conspicuous at farther than at closer lateral distances, which would produce an underestimation of true density.

(2) There was a significantly greater increase in the number of detections of rare than of common species. This result is of great interest since we are unable to categorize a species as conspicuous or inconspicuous on the basis of detectability profiles (because of the problems discussed earlier). Therefore, it becomes difficult to test whether the number of detections of inconspicuous and conspicuous species increase by the same proportionate amount. However, if we assume that, on average, inconspicuous species are rarer than conspicuous ones, we can conclude that the number of detections of inconspicuous species increased disproportionately more than for conspicuous species with the addition of a second observer.

(3) There was a significantly greater increase in the number of detections at farther than at closer lateral distances. This finding lends further support to the idea that the additional detections which resulted from use of a second observer came disproportionately from the least detectable species.

The mechanisms responsible for the increased detections upon the addition of a second observer are uncertain, but since the additional detections came disproportionately from rare species and from greater lateral distances, the simplest explanation is that two observers detect more birds by dividing their attention in different directions. The quick movement of an inconspicuous bird near an observer will be detected no matter what direction the observer is looking, while such movement at greater lateral distances will surely be missed by a single observer unless he or she is looking in the right place at the right time. This interpretation is consistent with the observation that the greatest proportion of additional detections came from the farther lateral distances. That proportionately few additional detections came from the abundant species probably means that a single person did well at detecting all individuals present and the second observer could add no additional detections (i.e., abundant species tend to be conspicuous). Alternatively, it is possible that observers become habituated or saturated at some point with the detections of abundant species and begin to ignore additional observations, thus adding relatively fewer detections of common species in larger samples. However, the sample area with two observers was no larger and, secondly, an additional observer should act to decrease such saturation effects and contribute additional detections if they existed. More definitive answers must await further work on this question.

It is interesting that the bulk of additional detections with a second observer were, in our case, recorded beyond 30 m (Table 3). Since fixed-width transects in forested areas are rarely wider than 30 m or so, the increase in detections that results from an additional observer may require a transect width wider than is practical for some habitat types.

The combined results suggest that use of an additional observer will minimize the differences in detectability among species and increase the overall detectability of each species within a fixed transect area. However, the accuracy of this and other methods needs to be established empirically from studies with banded birds where the true densities are known (see, for example, Järvinen et al. 1978a). The more usual comparisons of various transect methods with spot-map methods (Franzreb 1976, Dickson 1978, Järvinen et al. 1978b, Mikol et al. 1979) are interesting but still they do not reveal the accuracy of the transect methods because the spot-map method itself is subject to many possible inaccuracies (Svensson 1974b, Best 1975).

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