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Source: Journal of Wildlife Diseases, 29(2) : 284-289

Published By: Wildlife Disease Association

URL: https://doi.org/10.7589/0090-3558-29.2.284

Journal of Wildlife Diseases, 29(2), 1993, pp. 284-289

COUNTING DEAD BIRDS: EXAMINATION OF METHODS

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ABSTRACT: We studied three methods (line transect, circular quadrat, complete count) for estimating density of dead birds, using models of sparrows and meadowlarks placed at a density of 50 birds of each type/ha. Line transects with a 500-m search line were used in cultivated pasture and native prairie habitats. The number of birds found by individual searchers in line transects varied markedly, particularly, in pasture habitat. More birds were found, and birds were detected at a greater distance, in prairie than in pasture. More meadowlarks than sparrows were found in both habitats but the mean estimated density of meadowlarks was greater than that of sparrows only in prairie. The number of birds found during most searches was less than that suggested for estimating density accurately and longer search lines were required. Density estimates obtained using circular plots to sample 10% of the prairie area ranged from 20 to 80 birds/ha for meadowlarks and from 10 to 60 birds/ha for sparrows in prairie habitat. A complete search by 25 volunteers spaced at 4 m intervals detected 90% of meadowlarks but only 62% of sparrows in pasture habitat. Mean (SD) time for a single search, including searchers and recorders, was 3.0 (0.8), 1.5 (0.3), and 7.5 person-hours, for line transect, circular plot and complete search, respectively.

Key words: Mortality, density estimation, wild bird, methods, sampling.

INTRODUCTION

Significance of mortality of animals from infections, intoxications or other causes is often assessed by counting affected individuals. Because complete counts of wild animals are seldom possible, most investigations of disease in wildlife include estimates of the number affected. Methods for estimating animal numbers are well developed in wildlife ecology (Ralph and Scott, 1981; Davis, 1982) but the techniques have been applied infrequently in the study of disease epizootics, so that estimates in many studies of disease in wild animals have been merely guesses.

The objective of this study was to evaluate methods for estimating the density of model dead birds in a simulated epizootic. Emphasis was placed on the line transect method (Burnham et al., 1980) which, although used widely to estimate animal populations, seldom has been applied to the study of disease. It involves sampling a portion of a larger area, but in contrast with most sampling techniques, the size of the area sampled is not known beforehand. Four assumptions are important for reliable estimation by this method: objects directly on the transect line will not be missed; objects are fixed at the initial sighting distance; measurements are precise; and sightings are independent events (Burnham et al., 1980). These are met most easily with immobile objects so the technique appears appropriate for dead animals.

Limited testing was done of two other methods for comparison of relative bias and cost in terms of person-hours. A complete count of dead birds was attempted in one habitat type using a large number of volunteers who searched the total area. In the third method, circular quadrats representing 10% of the total area of one habitat type were searched.

MATERIAL AND METHODS

Two study areas measuring 100 m × 100 m (1 ha) were established during June in fields near Saskatoon, Saskatchewan, Canada (52°5′N, 106°35′W). One was in an ungrazed cultivated grass (*Agropyron cristatum*, *Bromus* spp.) pasture, the other was in an area of ungrazed native rough fescue (*Festuca altaica* subsp. *scabrella*) prairie. Grass in the pasture ranged from 30 to 70 cm in height and the growth was dense; the prairie had short (<30 cm), relatively sparse vegetation. Boundaries of each study area were marked by stakes at 2-m intervals so that the area could be divided in a 2- × -2-m grid. One hundred hand-painted clay models comprised of 50 resembling western meadowlarks (*Sturnella neglecta*) and 50 resembling savannah sparrows (*Passerculus sandwichensis*) (Fig. 1), were distributed in each study area to simulate a die-off. Each bird was assigned a location by choosing coordinates on the grid using random numbers. Birds were dropped over the shoulder at the site and were retrieved after completion of trials.

Ten line transect searches, each with a new searcher, were done in each habitat type. The searchers were volunteers, with no prior experience, to whom the purpose of the experiment and methods were explained and examples of clay birds were shown. Each searched along a 500-m line, composed of five parallel 100-m lines, marked beforehand with cord across the area. The location of the first line for each searcher was chosen randomly and subsequent lines were spaced 20 m apart. Searchers adhered strictly to the marked transect line. In five trials in each field, transects were oriented in a north–south direction, in the other five the lines were in an east–west direction. When a searcher saw a bird, he/she stopped, marked the site on the transect line with a small stake and with an arrow indicating the direction of the bird and then continued the search. Another person, who followed the searcher, determined the type of bird and measured the sighting distance and the perpendicular distance from the line to the bird. Time required to complete each trial was recorded. Because objects near the transect line are more likely to be detected than those distant from the line, and since not all objects will be detected, it is difficult to determine the size of area searched effectively. A number of methods for calculating the detection function have been proposed (Burnham et al., 1980) and several are available in a computer program, TRANSECT II (White, 1988) that was used in this study. Some are based on the perpendicular distance from the transect line to the bird and others are based on the sighting angle and sighting distance. The Fourier Series estimator, a nonparametric method based on perpendicular distance, is the default estimator. Burnham et al. (1980) described it as more robust than methods based on sighting angle and distance, and suggested that the latter should not be used if there was significant correlation between sighting angle and distance. This estimator was used in all trials because a significant correlation was found between sighting distance and sighting angle in some trials. Information from line transects was entered into program TRANSECT II and density was calculated. Accuracy in estimating the detection function using line transect increases with the number of objects detected and a minimum of 40 objects per search has been recommended (Burnham et al., 1980). White et al. (1989) suggested that a sample size of >40 may be needed to make "reasonably precise" estimates of density. Differences between mean number of birds found per transect, mean maximum perpendicular distance of birds from the line during line transects in the two habitats, and estimated density were examined by using two-way analysis of variance (SAS Institute, 1990). For the last analysis, the square root of density was used to make groups, that is, species within habitats, more homogeneous with respect to variability.

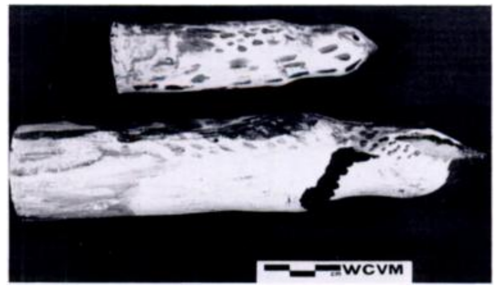

FIGURE 1. Examples of model meadowlarks and savannah sparrows used for trials.

The circular quadrat method was used only in the prairie. Each survey consisted of 20 nonoverlapping plots, each with an area of 50 m^2. Combined area of the 20 plots was equal to 10% of the total area. The location of plots was selected using a table of random numbers to identify coordinates of the center point. The center of each plot was marked with a stake and the circumference was measured with a 3.99-m cable attached to and rotated around the stake. Birds found within each plot were recorded. This procedure was done by two observers and repeated through 10 replications. The estimated density of the two species was compared by using a t-test (Brockett and Levine, 1984). Time required to complete each replicate was recorded.

A complete count was attempted once in the pasture habitat. Twenty-five volunteers were arranged at 4-m intervals along the length of a 100-m cord. They had no prior experience with this type of search but were shown samples of the model birds and given brief instructions prior to the search. The line of searchers walked slowly across the field, maintaining their position on the cord and indicating the location of birds found to three recorders who followed behind.

TABLE 1. Mean (SD) number of model birds found during ten line transect searches of 500 m length in two habitat types. Fifty meadowlark and 50 sparrow models were present/ha in each habitat.

Area	Number of birds found	
	Meadowlark	Sparrow
Pasture	11.5 (2.2)	7.1 (2.4)
Prairie	27.1 (4.6)	15.0 (2.8)

TABLE 2. Mean (SD) maximum perpendicular distance at which a model bird was detected during 10 line transect searches in pasture and prairie habitats.

Area	Distance (m)	
	Meadowlark	Sparrow
Pasture	4.3 (1.6)	3.4 (1.9)
Prairie	8.7 (1.3)	6.6 (0.9)

RESULTS

The mean number of birds of each species found per line transect search in prairie habitat was approximately twice as great as in pasture (Table 1). Differences in the number of birds found (model F = 76.6, $P < 0.0001$) was related to species ($F = 70.8$, $P < 0.0001$), habitat ($F = 143.5$, $P < 0.0001$), and their interaction (F = 15.41, $P < 0.0004$). The mean maximum perpendicular distance at which a bird was detected was less for both species in pasture than in the prairie (Table 2). The difference among groups was significant (model $F = 26.7$, $P < 0.0001$) with effects related to habitat ($F = 67.8$, $P < 0.0001$) and species ($F = 10.5$, $P < 0.002$), but not with their interaction. The suggested sample size of 40 was not attained for either species in either habitat type (Table 1). The estimated density of birds, based on all ten samples, is shown in Table 3. There were significant differences in density (model $F = 3.22$, $P = 0.034$) with an effect related to species ($F = 5.23$, $P = 0.028$) but not with either habitat or habitat-species interaction. More than 40 total birds were found during six of ten searches in prairie habitat. The estimated density of birds in these six trials is shown in Table 4.

The estimated density of birds in prairie, based on the number detected during ten circular quadrat surveys, each including an area equal to 10% of the total, ranged from 10 to 60 for sparrows ($\bar{x} = 39$, SD = 15), 20 to 80 for meadowlarks ($\bar{x} = 57$, SD = 22), and 60 to 130 for total birds ($\bar{x}$ = 93, SD = 25). The mean estimated density of meadowlarks was greater ($t = 2.14$, $P = 0.0461$) than the mean number of sparrows. The 25 volunteers, acting as a search line, found 45 (90%) of the meadowlarks and 31 (62%) of the sparrows in the pasture. Since a complete count was done only once sampling variance could not be estimated. The mean (SD) effort in person-hours for a single search (including the searcher and recorder) using line transect, circular quadrat and search line was 3.0 (0.8), 1.5 (0.3), and 7.5 hr, respectively.

DISCUSSION

Birds of both types were found during every search, so that the occurrence of mortality would have been detected by all of the methods used. Most methods underestimated the actual density of birds. The accuracy of search methods for bird carcasses has received relatively little attention and reported results are highly variable. For example, 81% of red-winged blackbird (*Agelaius phoeniceus*) carcasses placed within 20-×-5-m plots along transects in cattail (*Typha* spp.) marshes were found by searchers (Linz et al., 1991) and 75% of songbird carcasses placed beneath orchard trees were found (Tobin and Dolbeer, 1990), whereas searchers located only 6% of duck carcasses placed in a Texas marsh (Stutzenbaker et al., 1986). The lower frequency of detection of birds in pasture may be attributable to the tall grass in this habitat. During the complete search in the pasture no bird could have been further than 2 m from an observer yet only 62% of sparrows were found. Also, birds directly on the transect line in pasture were missed by searchers. This violates a basic assumption necessary for reliable estima-

TABLE 3. Mean (SD) estimated density of model birds based on ten line transects of 500 m length in two habitat types. The actual density was 50 birds of each type/ha.

Area	Density (birds/ha)			
	Meadowlark	(95% CI)	Sparrow	(95% CI)
Pasture	33.9 (7.3)	29.4 to 38.4	35.0 (28.6)	25.9 to 52.8
Prairie	52.8 (15.2)	43.4 to 62.2	30.4 (10.0)	24.3 to 36.6

tion with the line transect method. Tobin and Dolbeer (1990) reported that the lowest recovery success in their study occurred in an orchard with heavy ground cover. In our study, a difference in the detection of the two species was expected, as meadowlarks were larger and more brightly colored than sparrows and differences in detectability have been reported in similar circumstances (Linz et al., 1991). A difference in detectability may bias estimates of relative abundance of species that are not equally conspicuous in mixed species die-offs, as indicated by the results we obtained with the circular quadrat method. The line transect considers species-specific detectability during calculations but even based on this method, there was a greater estimated density of meadowlarks than of sparrows in the prairie habitat.

Transect lines must be of sufficient length to ensure that enough objects are detected to yield a reliable detection function. The appropriate length will vary with habitat type, detectability of the objects sought and the ability of the searcher. We chose a 500 m search line based on what we believed would be done if confronted with an apparently dense accumulation of dead birds under field conditions. This length was inadequate and the suggested minimum sample of 40 was attained only for total birds in prairie habitat. A pilot trial could be used to estimate an appropriate search line (L), using the formula $L = (N/n_1)(L_1)$, where N is the desired minimum number of objects (40) and n_1 is the number found during a pilot search of length L_1 (Burnham et al., 1980). Applying this formula to the number of birds found during our trials, the appropriate search line for sparrows in pasture would have ranged from 1,667 to 4,000 m for different searchers. On average, a 500-m search took 3.4 person-hours to conduct, excluding time required to establish the search line. An appropriate search for sparrow-sized birds in pasture-type habitat would require very substantial time input, particularly if the density of birds was lower than that in our experimental situation.

The line transect method was suitable for estimating the density of dead animals and it provided reasonable estimates of the density of total birds present in prairie habitat (Table 4). Some of the variation we encountered may be attributable to use of inexperienced volunteers. Burnham et al. (1980) and Linz et al. (1991) suggested that only competent, trained personnel should be used to reduce variation. Limitations of the line transect method include the need for at least two people (because the searcher must not diverge from the transect line), preparation to establish a transect line of known length, need for careful measurements, and relatively involved computa-

TABLE 4. Estimated density of total birds in prairie habitat based on six searches using the line transect method. The actual density of birds was 100/ha composed of 50 meadowlark and 50 sparrow models.

Search[a]	Density (birds/ha)	95% confidence interval
2	99	68 to 129
4	82	54 to 112
7	82	48 to 117
8	82	39 to 125
9	108	54 to 163
10	88	50 to 126

[a] Four additional searches were excluded because of low sample size (<40 birds found).

tions (although these can be done by computer).

The circular quadrat technique was comparatively easy to perform and calculations to estimate density were simple and could be done immediately. Using coordinates to locate the central point of sampling plots worked well and could be applied in the field by establishing a baseline through the area (Fredrickson et al., 1977). Circular plots could be located and searched by one person although it is easier with two people. Between-observer variation was not tested in this study as all plots were searched by the same two individuals. Because of this, direct comparison of the accuracy of circular quadrat and line transect methods was not possible. There was underestimation of the density of sparrows and slight overestimation of the density of meadowlarks with this method as a result of the difference in detectability. Estimates of density obtained during circular quadrat searches in this study should be considered with caution because the replicate surveys were done in the same area and some birds were found during more than one survey. This may have led to bias if there was an increased probability of detecting birds that had been found previously. The complete search method required about twice the effort in terms of person-hours/search of either the line transect or circular plot methods, missed many sparrow-size birds, and would be difficult to implement in most field situations; consequently this method is not recommended.

A basic problem with any technique lies in assessing its accuracy under the specific conditions being investigated. In our study there was a high density of birds distributed randomly in relatively homogeneous cover, the birds were not disturbed by scavengers, and the total area involved in the epizootic was known. These conditions differed from those in actual epizootics. Under natural conditions, initial sampling should be used to determine the extent of the area involved, the distribution of carcasses and the most appropriate method and level of sampling. Dead animals, marked and left in place prior to searches, could be used to measure the accuracy of the sampling method and would also allow use of capture/recapture calculations as another method for estimating the number of animals present.

ACKNOWLEDGMENTS

The assistance of colleagues who participated as volunteer searchers is gratefully acknowledged, as are the helpful suggestions by F. A. Leighton, J. R. Carey, and an anonymous reviewer, regarding manuscript preparation.

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Received for publication 14 May 1992.