Problems of Estimating Northern Bobwhite Populations at Low Density

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Abstract: A known population density was established for northern bobwhites (*Colinus virginianus*) on a 100-ha pasture. Line transects were walked twice/day for 5 days to obtain a density estimate. Twelve density estimators using the line-transect data were compared to the known bobwhite density. On our study area, 6 estimators overestimated bobwhite density and 6 of them underestimated density. Because few coveys were flushed, individual transect replicates had to be pooled to provide estimates. This pooling of replicates did not enable us to calculate a mean density and specific variances for each estimator. Variances produced by a Jackknife method appeared to underestimate the true variances. During years of low bobwhite densities (which are common), use of line-transect methods may be inappropriate. Capture-recapture data, collected 1 week prior to running the line transects, underestimated quail density on the pasture.

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The ability to accurately estimate northern bobwhite densities is important in developing management plans throughout its range. The line transect (LT) procedure has been used extensively to estimate wildlife densities. Burnham et al. (1980) and Guthery (1988) have provided theory, methodology, approaches, and problems associated with the technique. Recently, Guthery (1988) evaluated LTs for estimating bobwhite density on southern Texas rangelands. He concluded that LTs are a reliable method for obtaining precise estimates of bobwhite density. Similarly, Ratti et al. (1983) used LTs to estimate gray partridge (*Perdix perdix*) densities on South Dakota cropland and believed the method resulted in accurate and precise density estimates. Brennan and Block (1986) also employed LTs to estimate mountain quail (*Oreortyx pictus*) densities in northern California. Although they could not rigorously assess the accuracy of their density estimates, they felt LTs provided more reliable density estimates than the strip census method. Despite the apparent agreement among researchers regarding the reliability of LTs, little research has focused on testing the accuracy of the technique. We tested the accuracy of 12 LT estimation procedures by comparing estimates with a known density of bobwhites. In this paper, we provide information on the problems of using LT methods to estimate bobwhite densities when populations are at low numbers.

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Study Area and Methods

This study was conducted on the La Copita Research Area, a 1,093-ha ranch owned and operated by TAES in Jim Wells County, Texas. La Copita is located in the transitional zone between the South Texas Plains and Gulf Prairies and Marshes (Gould 1975). Predominant range sites are sandy loams and gray sandy loams characterized by vegetation ranging from open grassland to dense stands of brush (Wilkins 1987). The vegetation was described by Walsh (1985) as Tamaulipan thorn-scrub woodland.

LT censusing efforts focused on approximately 100 ha of rangeland double-chained, raked, stacked, and burned during winter 1978 (Scifres and Koerth 1987). The area is used currently for research on prescribed burning and herbicide application in managing brush regrowth. As a result of the chaining operation and follow-up treatments, the woody vegetation is younger, shorter, and less dense than the rest of the research area. Consequently, bobwhites prefer the chained pasture, as quail traditionally have been more abundant there than elsewhere on the research area.

During October 1988, bobwhites were live-trapped on the chained pasture as part of the annual fall census. Nine birds, from discrete coveys, were fitted with radio-transmitters before release. Covey sizes were recorded for each covey captured by counting all birds inside and outside of traps. Each radio-marked bird identified a specific covey and these coveys represented a population of known density.

Immediately before each LT censusing session, each radio-marked covey was located via triangulation to determine the number of marked coveys and birds/covey present on the study area and thus, the known population size for that particular censusing session. Recounts of birds in flushed, radio-marked coveys during and after completion of all censuses indicated the birds/marked covey remained constant throughout the 5-day study. Activity switches on 7 of the radio transmitters aided in determining bird survival. Marked coveys that had moved off the area were not considered part of the known population. As a result of occasional egress, known population size varied over the course of the evaluation period.

Beginning on 24 October 1988, 4 LTs about 1-km long, were walked alternately from north to south twice a day (early morning and late afternoon) for 5 consecutive

Table 1. Date, time (morning or afternoon), distance walked (km), number of marked coveys flushed (number in parenthesis equals percent of marked coveys flushed), size of marked coveys, flushing distance (m), flushing angle, and total marked coveys of northern bobwhite on study area at time LTs were walked, October 1988.

Date	Time	Distance walked	*N* Coveys flushed	Covey size	Flushing distance	Flushing angle	Total marked coveys on area
24 Oct	AM	4.64	0 (0)				9
	PM	4.64	1 (14)	9	11.6	237	7
25 Oct	AM	4.64	1 (14)	10	8.8	283	7
	PM	3.56	1 (14)	6	13.7	288	7
26 Oct	AM	4.64	0 (0)				8
	PM	4.64	1 (14)	7	6.4	218	7
27 Oct	AM	4.64	1 (11)	4	8.7	237	9
	PM	4.64	1 (13)	4	1.8	351	8
28 Oct	AM	4.64	0 (0)				8

days (Table 1). Each time, the starting point for the first LT was located randomly and thereafter a 200-m interval was established between LTs. During each censusing session a pair of observers walked each LT. The first observer maintained directional bearings, recorded the number of coveys flushed/transect, the radial flushing distance, the flushing angle and estimated covey size. The second observer, following about 15 m behind the first, carried a portable receiver and antenna and determined whether each covey flushed was radio-marked.

The program LINETRAN (Gates 1981*a*) was used with data collected for radio-marked coveys flushed during the LT sessions to obtain 12 estimates of density (Table 2). LINETRAN is a Fortran computer program that computes a variety of

Table 2. LINETRAN transect population estimation procedures used in comparison to known population of northern bobwhite in Texas, 1988.

Method	Reference
Exponential, Gamma distribution $- a = 1$	Gates et al. 1968
Exponential, Gamma distribution $- a = 2$	Gates 1969
Fourier Series	Crain et al. 1978
Generalized Exponential	Pollock 1978
Geometric	Gates 1969
Hayne Constant Radius	Hayne 1949
Hemingway Normal	Hemingway 1971
Modified Hayne	Burnham and Anderson 1976
Polynomial Nonparametric	Gates 1981*a*
Quadratic Exponential	Burnham et al. 1980
Quadratic Nonparametric	Anderson and Pospahala 1970
Splined	Gates 1979

estimators for LT methods of sampling biological populations. No estimator given is best under all conditions, hence the necessity for a variety of estimators covering a variety of situations. The Polynomial Nonparametric, Fourier Series, Quadratic Nonparametric, Splined, Quadratic Exponential, and Generalized Exponential estimators provided by LINETRAN will properly handle (right) truncated data sets. Histograms (raw, ungrouped and grouped data) are printed to further aid the user in interpreting results. LINETRAN calculates densities for grouped data using exact maximum likelihood procedures (following Burnham, et al. 1980) for the Quadratic Exponential, Generalized Exponential, and Fourier Series estimators. These and other characteristics of LINETRAN are explained at a greater length in the user's guide (Gates 1981*a*).

Estimates were compared with the coveys known to be on the study area (obtained through radio-telemetry prior to each session) to evaluate the accuracy and precision of each estimator. Because of small sample sizes (Table 1), LINETRAN could not calculate a density estimate for each morning or evening replicate. Therefore, all transects were pooled to form 1 long (40.7− km) transect. Variances for each estimator had to be calculated using a Jackknife method (Gates 1981*a*). Basically, the method requires a series of natural subunits (each morning or evening run). The set of data from each subunit is omitted, 1 at a time, with the density estimated from the remaining data. These densities are called pseudovalues and are used to calculate the average density and its variance.

Population density also was calculated without using LINETRAN following the methods of King and Hayne (Overton and Davis 1969). These methods allowed calculation of a mean densities and variances.

Population density estimates obtained from 10 days of capture-recapture data conducted 1 week prior to running the LTs also were compared to estimates obtained from LINETRAN, the King and Hayne methods, and to the known population. The program CAPTURE (Otis et al. 1978) was used to obtain the capture-recapture estimate.

Results

Mean size of flushed radioed coveys for the chained pasture was 6.7 quail (Table 1). Therefore, by multiplying the mean number of coveys present (7.8) with the mean covey size and dividing by the size of the study area (100 ha), a known mean density of 0.52 birds/ha was calculated (Table 3). When compared to the known bobwhite density, the Geometric estimator generated the most accurate density estimate (Table 3), but slightly underestimated density. The Generalized Exponential procedure provided the least accurate estimate, followed closely by the Exponential, Gamma Distribution (a = 2) and Fourier Series (Table 3). The Polynomial Nonparametric, Quadratic Nonparametric, and Splined estimators had the greatest precision (i.e., lowest coefficient of variation, Table 3). Conversely, the Modified Hayne, Fourier Series, Exponential, Gamma Distribution (a = 1), and Hayne Constant Radius procedures generated the least precise estimates.

Table 3. Northern bobwhite density estimates and variances (numbers rounded to nearest 1/100) obtained from program LINETRAN for various population estimation procedures for a known population of northern bobwhite in Texas, 1988.

Method	Density (birds/ha)	Variance of mean density	Coefficient of variation
Known Population	0.52	0.00	0.01
Exponential, Gamma Distribution − a = 1	0.66	0.20	0.68
Exponential, Gamma Distribution − a = 2	0.74	0.03	0.23
Fourier Series	0.28	0.05	0.80
Generalized Exponential	0.27	0.01	0.37
Geometric	0.48	0.03	0.36
Hayne Constant Radius	0.63	0.10	0.50
Hemmingway Normal	0.35	0.01	0.29
Modified Hayne	0.42	0.17	0.98
Polynomial Nonparametric	0.57	0.00	0.00
Quadratic Exponential	0.33	0.02	0.43
Quadratic Nonparametric	0.57	0.00	0.00
Splined	0.57	0.00	0.00
Darroch Estimator	0.38	0.00	0.00

Estimates obtained from the hand-calculated King and Hayne methods both gave a mean density of 0.78 quail/ha with a coefficient of variation equal to 0.86 quail/ha. When all replicates were pooled (which had to be done to use LINETRAN), the King method gave an estimated of 0.58 quail/ha and the Hayne method gave an estimate of 0.75 quail/ha. With the pooled transect data there was only 1 density estimate and no variance could be calculated (unless the Jackknife or other such methods were used).

Program CAPTURE, selecting the Darroch estimator with capture probabilities varying with time, gave an estimate of 38 quail with a coefficient of variation equal to 0.0004. Dividing this estimate (38 quail) by area (100 ha) gave a density estimate of 0.38 quail/ha.

Discussion

Our results agree with Tilton et al. (1987) who noted that line-transect-estimation techniques produced varying degrees of accuracy and precision when applied to deer populations. For our data on quail, 6 methods overestimated bobwhite density and 6 of them underestimated density with varying degrees of precision (Table 3). Some methods appeared to have reasonably accurate and precise estimates. However, because of the low quail density on our study area, LINETRAN could not calculate density for each replicate (each morning or evening run), which did not enable us to calculate a mean density and specific variances for each estimator. Without the aid of Jackknife or other such methods, variances of mean density could not have been calculated for each estimator. Overton and Davis (1969:422) recommend that variances be obtained by estimating the mean density from several random transects and then calculating the variances among these estimates. They further stated that formulae exist for direct estimates of the variance of several LT methods, but concluded "these are not likely to be of value." Comparing the low variances produced by the Jackknife method (Table 3) with those produced by the King and Hayne estimates, we are inclined to agree that the Jackknife method underestimates the true variances. This underestimation of the variances might falsely indicate the procedure's precision. Further work is needed to determine if this is a problem of low sample size that may not prevail when quail are numerous.

If low bobwhite densities preclude using individual replicates to obtain a mean density and variance because few birds are flushed, then little confidence can be placed on density estimates and precision of these estimates. Interestingly, mean density and variance can be calculated by hand using population estimation procedures (King and Hayne methods) even when quail densities are low. The calculated variances were large, but appear reasonable considering the variability among replicates. When bobwhite populations are at low levels, the use of LT methods to determine density may be questionable because the variance of mean density must be calculated by using Jackknife or other such methods.

It is conceptually wrong (especially with only 1 replication) to evaluate or select LT estimators by computing several of them to find the 1 that is closest to the true density; 10 or 20 (or more) such studies are needed to really evaluate a method (Burnham, pers. commun.). Our objective was not to select the "best" LT estimator, but to point out that when study areas are small and quail densities are low, LT methods may not be appropriate. Further, we contend that these conditions are common with northern bobwhite studies. Burnham (pers. commun.) states that LTs are especially good for estimating density of conspicuous species over a large area when densities are low; however, a sufficient sample size of detections is necessary, which means traversing enough lines to get a large sample of flushes. Conversely, when sample sizes are low for any size study area, reliable results will not be obtained.

Guthery (1986:142) recommended walking 4 (1.6-km long) transects/259 ha a minimum of 3 times (total length of transects 19.2 km) to obtain density estimates of northern bobwhite on rangelands of Texas. He further stated if time permitted, it was better to walk each of the 4 transects 5 times (total length of transects 32 km). We walked 4 random transects (1-km long) during each of 5 consecutive days for a total of 47 km in an area of 100 ha. However, because of the small number of covey flushes, LT methods recommended by Burnham et al. (1980), Gates (1981*b*), and Guthery (1986) could not be used as presented. One could overcome this by running more transects or extending the length of the transects, although this would be time consuming and costly. Guthery (1986:144) estimated 99 cents/ha of area counted.

During years of low population levels, these methods may be inappropriate. Lehmann (1984) noted that fluctuation in bobwhite density can occur from 1 year to the next, resulting in high densities or conversely, low densities. Roseberry and Klimstra (1984:122) listed 19 studies ranging from 27 to 6 years duration; mean densities ranged from 1.64 (10-year study) to 0.14/ha (22-study). In 7 of the 19 studies, the mean density of quail was below that in our study. If low densities are as common as indicated by Roseberry and Klimstra (1984), then methods other than LTs should be used.

The 10-day capture-recapture estimate we obtained underestimated the known density but had good precision. The Darroch estimator from program CAPTURE gave the total number of marked quail on the last day as an estimate even though there were nonmarked quail captured within all samples taken. In fact, if only the first 9, 8, or 7 days of data were used, the Darroch estimator always gave the total number of marked quail on the last day as its estimate for the population. Also, the small standard deviation produced by this method appeared to underestimate the variability within the capture-recapture data. We recommend that the variance be obtained by estimating population density from several replicate sets of capture-recapture data, and then the variance be calculated among these estimates. Overton and Davis (1969:422) stated that formulae for direct estimates of variance of LT methods are of little value; we also consider the formula for direct estimates of variance of capture-recapture methods not to be of value. Low quail numbers only add to the problem of obtaining replicate samples. Therefore, capture-recapture methods also are not recommended to estimate bobwhite numbers during years of low density. Further study is needed to determine the quail density (number of coveys flushed), size of area, or length of transect needed before either LINETRAN or program CAPTURE would be effective.

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