Accuracy and Precision of Line Transect Procedures for White-tailed Deer

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Abstract: White-tailed deer (*Odocoileus virginianus*) densities and sex ratios were determined during 2 seasons for a semiconfined population. Two drive counts were used to estimate deer densities when an entire area was traversed, once in early winter and once in summer. In addition to the 2 drive counts, 5 random transects, totaling 4.5 km, were walked 6 times (3 times in fall and 3 in summer). Eighteen different density estimators were calculated using the line transect data. Compared to the density estimates derived from drive counts, the Hayne Constant Radius estimator gave the most accurate estimate for fall-gathered data, while the Exponential estimator gave the most accurate estimate for summer-gathered data. Considering both fall and summer estimates, the Generalized Exponential procedure was the most accurate. Precision was greatest with the Polynomial, Triangular, and Exponential procedures for summer, fall, and combined surveys, respectively. High variability, associated with estimates (and therefore lack of precision), suggests research is needed on the applicability of models to data obtainable during helicopter surveys or other methods. Buck-to-doe ratio estimates from the line transects were greater ($P < 0.05$) than those derived from the drive counts.

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Burnham et al. (1980) listed 4 assumptions critical to the achievement of reliable density estimates from line transect sampling: (1) objects on the line are never missed, (2) objects do not move before being detected, (3) there are no measurement or rounding errors, and (4) sightings are independent. With the exception of

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the first, none of these assumptions are met for white-tailed deer. However, line transect sampling can be an important tool for managers, and therefore, those estimators that are least affected by violations to these assumptions should be acknowledged. Burnham et al. (1980) recommended use of models that are robust, i.e., those which produce density estimates that have a small degree of bias relative to their standard error. Of 26 estimators Burnham et al. (1980) compared, only the Quadratic Nonparametric (Anderson and Pospahala 1970), Fourier Series (Crain et al. 1978), Polynomial (Gates 1981) and Hayne (Hayne 1949, Burnham and Anderson 1976, Burnham 1979) met robustness criteria.

Our objective was to test the accuracy and precision of line transect estimation procedures for white-tailed deer by comparing estimates with the results of drive counts. A second objective was to determine the accuracy of deer sex ratios obtained from line transects.

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Methods

Study Area

Lake Fairfield is situated in the Post Oak Savanna ecological area of Texas (Gould 1962). During the study, deer were concentrated on a peninsula of approximately 150 ha near a steam generating plant (Fig. 1). The generating plant, Lake Fairfield, a cooling water intake canal, and a hotwater discharge canal, surrounded the peninsula. Two constrictions in the peninsula divided it into 3 areas of approximately 15.3 ha, 65.0 ha, and 69.7 ha. The peninsula provided habitat for a discrete deer population with limited egress and ingress due to hot and/or fast moving water in the discharge and intake canals, fencing and intensive human activity around the power plant, and the broad expanse of water in Lake Fairfield. Hunting was prohibited.

Deer Drives

Deer drives were conducted on 3 December 1983 and 3 July 1984 by traversing the peninsula with a line of 15 and 13 students, respectively, at intervals of no more than 50 m. Each student counted all deer that crossed through the line to his right. Students at the ends of the line and at the end of the drive recorded any deer attempting to swim from the area. Each deer was classified according to sex (buck, doe, or undetermined), age (<1 year old, >1 year old, or undetermined), and antler characteristics (spiked, branched, absent, or undetermined).

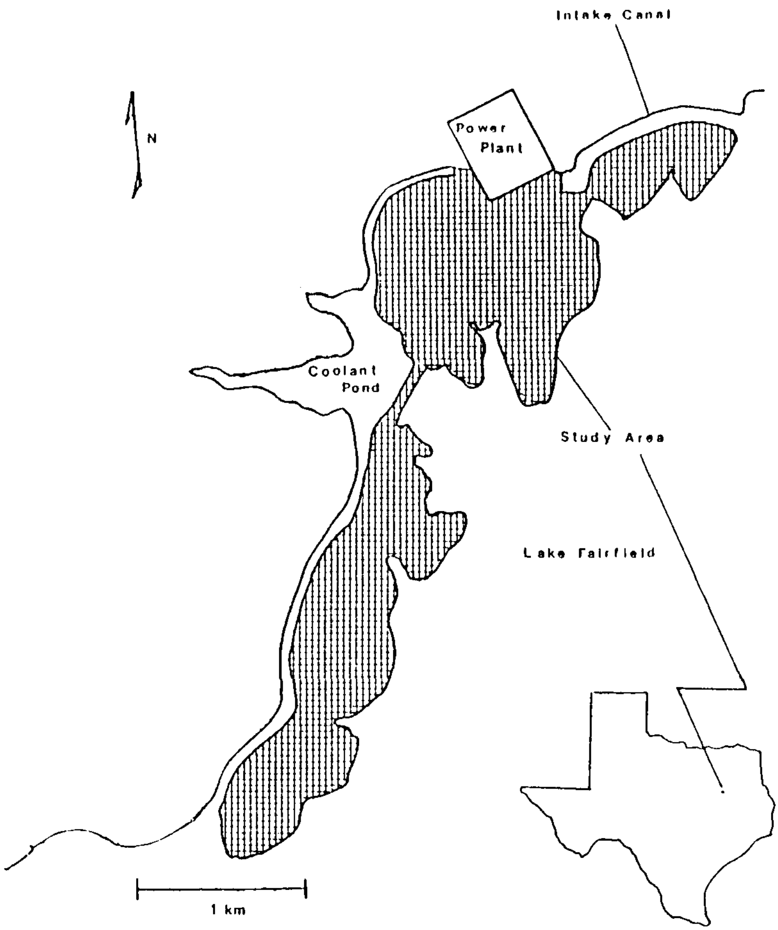

Figure 1. Location of white-tailed deer surveys, Lake Fairfield, Texas, 1983–1984.

Line Transects

Five randomly located transect lines totaling 4.5 km were used for the line transect survey. Sex, age, sighting distance, perpendicular distance, and sighting angle were recorded for each deer seen while walking each line on separate evenings at dusk. When 2 or more deer were encountered within approximately 5 m of each other, the data were treated as a single point and group sizes were incorporated into the analyses. Distances were estimated with a rangefinder, and sighting angles were estimated with a compass. Each transect was walked 3 times between 12 September and 14 November 1983 (fall), and 3 times between 17 May and 1 July 1984 (summer). Within season, the data were lumped and treated as 1 transect totaling 13.5 km. This increased observations to numbers that conformed to Burnham et al.'s (1980) recommendation that studies should be designed to allow at least 60 to 80 observations. The program, LINETRAN, developed by Gates (1981) was used to obtain 18 estimates of density for comparison with the drive counts. All data were used and data sets were not truncated. Coefficients of variation (CVs) were used to measure variability. Buck-to-doe (adult and yearling bucks-to-adult and yearling does) ratios were calculated from each of the 3 surveys in each season, and results were averaged to produce overall buck-to-doe estimates for each season.

Results and Discussion

Deer Drives

During the drive surveys on 3 December 1983 and 3 July 1984, volunteers counted 155 and 142 deer, respectively. These numbers were used to estimate densities of 1.03 deer/ha and 0.95 deer/ha, respectively, for the 2 drives.

McCulloch (1979) found considerable problems with drive surveys used at George Reserve, Michigan. Sources of error included: (1) variation in drive procedures, (2) cryptic behavior on the part of the deer, (3) weather-influenced deer behavior, and (4) dense vegetation, rough terrain, or inclement weather impairing the performance of the drivers. McCulloch (1979) found the reconstructed population was far more reliable for estimating numbers than the drive count. Reconstructing a deer population entails accounting for all deer after their death and estimating their age.

Population reconstruction was beyond the scope of this study; however, we believe we missed few deer. McCulloch (1979) improved drive counts, when compared with the population reconstruction method, by increasing the number of counters. Hence, in the years just prior to publication of his studies, 80 to 100 drivers (or about 1 per 5 ha) participated in the counts on the roughly square area. The study area was relatively linear. This allowed drivers to cover a larger area while maintaining between-driver distances, which allowed each driver to carefully survey the space between him and the next driver. Approximately 52% of the study area was open grassland. These features enabled the drivers to maintain visual contact with adjacent drivers throughout virtually all of the count. Further, because of its unique shape (Fig. 1), the area was easily divided into 3 separate counts. The 13 and 15 drivers in the summer and winter counts, respectively, covered 3 separate areas, the largest of which was 69.7 ha. Minimum driver density was comparable to McCulloch's improved count, and the counters were covering a linear, rather than a square area. Therefore, between-driver distances averaged less in this study than at George Reserve. McCulloch (1979) also improved the George Reserve deer drives by reorganizing his volunteers at 2 north–south lines across the reserve. The 2 constrictions in the present study area allowed complete regrouping and reorganization with a minimum risk of undetected deer passing through the line in the process.

Understandably, the December and January weather at George Reserve often proved detrimental to the efficiency of the drivers. The weather, during drives in east Texas, was relatively mild. Therefore, we believe the weather did not affect the efficacy of the drivers in the study. Further, the vegetation is not believed to be as dense, nor is the terrain as rugged, as that at George Reserve. Nevertheless, if any deer succeeded in passing through the line undetected, it would have done so through the use of occasional areas of tall grass or thick woody vegetation. The risk of this occurring was greatest during the summer.

Because of some of the factors reported in McCulloch's (1979) work, there may be a small degree of error in the drive counts, particularly during summer. At George Reserve, McCulloch found, at high population levels, the use of the drive count overestimated the population, due to duplicate or otherwise erroneous reportings. Our density of 1 deer/ha is high; therefore, inaccuracy in the drive count would probably produce an overestimate.

Line Transects

During fall transects, 161 deer (90 groups of 1–6 deer) were recorded. During summer transects, 93 deer (60 groups of 1–4 deer) were recorded.

When applied to fall transect data, the Hayne Constant Radius estimator was closest to the deer density estimate obtained from the December drive count (Table 1). The validity of the Hayne estimator depends on the critical assumption

Table 1. White-tailed deer density estimates for various population estimation procedures used with data from line transects. Lake Fairfield, Texas, 1983–1984.

Method and author(s)	Density (deer/km^2)	SE	95% CI Lower	95% CI Upper	CV (%)
Deer drive					
Summer	94.7				
Winter	103.3				
Eberhardt-Cox[a] (Eberhardt 1978)					
Summer	80.2	28.8	23.8	136.4	35.9
Fall	86.5	29.0	29.7	143.3	33.5
Exponential (a = 1; Gates et al. 1968)					
Summer	61.3	19.0	24.1	98.5	31.0
Fall	64.1	27.9	9.4	118.8	43.5
Exponential (a = 2; Gates 1969)					
Summer	95.8	16.6	63.3	128.3	17.3
Fall	143.1	25.2	93.7	192.5	17.6
Fourier series (Crain et al. 1978)					
Summer	73.2	13.9	46.0	100.4	19.0
Fall	187.5	106.7	0	396.6	56.9
Generalized exponential (Pollock 1978)					
Summer	87.9	8.8	70.7	105.1	10.0
Fall	107.7	54.1	1.7	213.7	50.2
Geometric (Gates 1969)					
Summer	54.1	11.6	31.7	76.8	21.4
Fall	87.2	12.9	61.9	112.5	14.8
Hayne constant radius (Hayne 1949)					
Summer	67.0	21.8	24.3	109.7	32.5
Fall	104.4	15.7	73.6	135.2	15.0
Hemingway normal (Hemingway 1971)					
Summer	63.8	21.2	22.2	105.4	33.2
Fall	76.6	18.0	40.6	112.6	23.5

Table 1. (continued)

Method and author(s)	Density (deer/km^2)	SE	95% CI Lower	Upper	CV (%)
Kelker index[a] (Kelker 1945)					
Summer	68.1	22.8	23.4	112.8	33.5
Fall	77.4	21.0	36.2	118.6	27.1
Modified Hayne (Burnham and Anderson 1976)					
Summer	75.2	31.4	13.7	136.7	41.8
Fall	87.7	20.2	48.1	127.3	23.0
Polynomial (Gates 1981)					
Summer	158.6	12.2	134.7	182.5	7.7
Fall	345.4	168.0	16.1	674.7	48.7
Polynomial[a] (Gates 1981)					
Summer	74.4	19.6	36.0	112.8	26.3
Fall	82.1	19.7	43.5	120.7	24.0
Quadratic (Anderson and Pospahala 1970)					
Summer	170.5	27.7	116.2	224.8	16.2
Fall	314.7	130.8	58.3	571.1	41.6
Quadratic[a] (Anderson and Pospahala 1970)					
Summer	85.4	37.2	12.5	158.3	43.6
Fall	93.0	32.0	30.3	155.7	34.4
Splined (Gates 1979)					
Summer	277.6	84.3	122.37	442.8	30.4
Fall	298.4	69.5	162.2	434.6	23.3
Splined[a] (Gates 1979)					
Summer	68.1	22.8	23.4	112.8	33.4
Fall	77.4	21.0	36.2	118.6	27.1
Triangular (Gates 1981)					
Summer	139.6	57.4	98.4	180.8	41.1
Fall	145.7	12.0	122.2	169.2	8.2
Triangular[a] (Gates 1981)					
Summer	81.1	26.1	29.9	132.3	32.2
Fall	92.6	22.1	49.3	135.9	23.9

[a]LINETRAN grouped the data into distance classes of 26 and 33 m, respectively, for the fall and winter transects.

that the expected average sighting angle is 32.7° (Burnham et al. 1980). The average sighting angles for the summer and fall transects, respectively, were 27.2° and 36.3°. Deviations from 32.7° were not significant ($P > 0.05$). Burnham et al. (1980) found the Hayne method to be a robust estimator, providing the critical assumption was met. The Exponential ($a = 2$) estimator for summer density was closest to the density estimate obtained from the summer drive count. Burnham et al. (1980) stated the primary weakness of this method was due to its underlying assumption: the detection model is based on an exponential frequency distribution. They suggested such a distribution was a restrictive, special case, and therefore was not applicable for most purposes. Overall, the Generalized Exponential procedure was most accurate. Relative to the other parametric models employed by LINETRAN, this model was flexible (Gates 1981). It fits a wide variety of habitats sampled, different observers, and other variable conditions typical of line transect censuses. Behavioral differences among the deer in the 2 seasons, and changes in visibility associated with seasonal changes in vegetation were thought to account for the lack of consistency in the accuracy of estimators among seasons.

Percent CVs for the fall Hayne estimates, summer Exponential (a = 2) estimates, and fall and summer Generalized Exponential estimates were 15.0, 17.3, 50.2, and 10.0, respectively. With the exception of application of the Generalized Exponential estimator to the fall transect data, each of the most accurate estimators noted above was characterized by reasonable levels of precision, compared to other commonly used survey techniques. Beason (1979), Beason et al. (1986), DeYoung (1985), and Teer et al. (1985) reported percent CVs of 8–18, 19.6–69.9, 2.9–9.7 and 2.4–21.9, respectively, from helicopter surveys. Farfarman and DeYoung (1986) reported percent CVs of 26.3 and 27.1 from spotlight surveys.

The Exponential (a = 2) procedure had the greatest precision for summer and fall combined data. The Triangular procedure, which, like the Exponential procedure, is based on a restricted, special case frequency distribution (Burnham et al. 1980), had the greatest precision for fall data. The Polynomial procedure had the greatest precision for summer estimates. Burnham et al. (1980) reported the Polynomial estimator met robustness criteria and was a generally useful method.

Time and manpower constraints precluded replication of surveys in the present study. Further research is needed to assess applicability of line transect models addressed herein to helicopter and spotlight surveys. In the study, the broad time frame of surveys, even without replication, may have introduced additional error into the results, due to recruitment, mortality and egress.

Thirteen of the 18 procedures underestimated the deer drive population estimates during summer sampling (Table 1). However, during fall only 10 underestimated the drive estimates. Results suggest that transect estimation techniques can produce a wide range of estimates with varying degrees of accuracy and precision.

When line transect data were used, the estimate of buck-to-doe ratios was greater ($P < 0.05$) than when drive data were used. The buck-to-doe ratios produced from the drive counts and walk transects were 0.12 and 0.25, respectively, during fall counts; and 0.05 and 0.16, respectively, during summer counts.

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