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AERIAL CENSUSING OF WHITE-TAILED DEER AND COMPARISON TO SEX-AGE-KILL POPULATION ESTIMATES IN NORTHERN INDIANA

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ABSTRACT: Accurate estimates of population size and composition are important for effective deer management. White-tailed deer (*Odocoileus virginianus*) population estimates were obtained in two northern Indiana Counties, Marshall and Steuben, by winter aerial censusing in 1990 and 1991. To optimize helicopter flight time and decrease the variance among sample areas, stratified random sampling with optimal allocation was used to census 25% of each County. Ground truthing a subsample of woodlots provided a check on the accuracy of the aerial counts. Mean posthunt deer density calculated from aerial counts was 0.09 deer/ha in Steuben County in 1990 and 1991. In 1991, mean deer density in Marshall County was 0.04/ha. Compared to combined ground counts, the aerial counts were 93% accurate. Stratified counts from a helicopter were relatively accurate for northern Indiana when adequate snow cover was present. Population estimates from aerial counts approximated the sex-age-kill model estimates.

KEYWORDS: Aerial censusing, ground truthing, population estimates, sex-age-kill model, white-tailed deer.

INTRODUCTION

Effective management of deer populations requires accurate estimates of population size and composition. Managers want to maintain a healthy deer herd while preventing overpopulation and subsequent habitat damage. Before harvest levels can be decided, the size and composition of the herd and/or any growth trend in the deer population must be determined (Conner, *et al.*, 1986). Small differences in doe harvest rates markedly affect the direction and magnitude of population change in response to hunting (Downing, 1981). Without accurate population estimates, harvest management must proceed conservatively, leaving more individuals than may be required for maintaining a healthy and stable population. At the time of this research, the Indiana Division of Fish and Wildlife was using the sex-age-kill method (Eberhardt, 1960) to estimate deer population size; the accuracy of this method has not been tested within the State.

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Aerial surveying has been used under various conditions to census cervids (Siniff and Skoog, 1964; Bartmann, *et al.,* 1986; Beasom, *et al.*, 1986; Gasaway, *et al.,* 1986; Stoll, *et al.*, 1991). The accuracy of helicopter counts varied tremendously, depending on habitat, terrain, and method. Beasom, *et al.* (1986) reported 33% accuracy in the brushy rangelands of Texas, while accuracy approaching 99% was found for the snow-covered, predominantly agricultural lands in northwestern Ohio (Stoll, *et al.,* 1991). Aerial surveying with proper snow cover (Bartmann, *et al.*, 1986) can provide a reasonably accurate deer count in winter. To determine the accuracy of aerial counts, ground counts should be conducted for comparison (Pollock and Kendall, 1987; deCalesta and Witmer, 1990; Stoll, *et al.,* 1991). Our goal was to obtain independent deer population estimates from both aerial and ground counts and then to compare these counts to Indiana Division of Fish and Wildlife deer density estimates for two northern Indiana Counties made using the sex-age-kill model.

MATERIALS AND METHODS

Marshall and Steuben Counties were selected as the two study areas because they are highly likely to be snow covered in winter; the Counties differed in percent forest cover, degree of woodland fragmentation, and mean deer density. Steuben County is located in the northeastern corner of Indiana, and Marshall County is in north-central Indiana. Both Counties are part of the Northern Lakes Natural Region of Indiana (Homoya, *et al.,* 1984). The dominant trees in this Natural Region are oaks and hickories. Red oak (*Quercus rubra*), white oak (*Q. alba*), black oak (*Q. velutina*), shagbark hickory (*Carya ovata*), and pignut hickory (*C. glabra*) are dominants in the dry and dry-mesic upland forests; beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), black maple (*A. nigrum*), and tulip tree (*Liriodendron tulipifera*) are dominant at mesic sites (Homoya, *et al.,* 1984). Approximately 18% of Steuben County is comprised of forested fragments; many lakes, creeks, and other wetland areas occur as well. Approximately 11% of Marshall County is forested, and the County has a much smaller area covered by lakes, creeks, and wetlands. Woodlots in Steuben County tend to be larger and more contiguous than those in Marshall County. Row crops (corn and soybeans) and hay/pasture fields are the dominant plant communities in both Counties. Mean deer density (estimated by the sex-age-kill model from harvest data) for 1987-1989 was 0.10 deer/ha (0.04/ac) in Steuben County and 0.06 deer/ha (0.02/ac) in Marshall County.

Aerial Surveying. Aerial censusing of diverse habitats can be both bias-prone and expensive. Rental costs during 1990-1991 ranged from $180/hr for the Indiana Division of Fish and Wildlife helicopter to $750/hr for a commercial helicopter and pilot. Total census costs are substantial because they include both the time needed to conduct the surveys and the air time to and from the study areas. Ground counts were conducted to estimate the accuracy of the aerial counts (Stoll, *et al.*,1991). Stratified random quadrat sampling with opti-

mum allocation was used to decrease variance among sample areas and to best utilize flight time (Siniff and Skoog, 1964; Gasaway, *et al.*, 1986).

Twenty-five percent of each County was censused, and both were divided into 2.6-km^2 (1-mi^2) quadrats following the section lines on U.S. Geological Survey 7.5 minute topographic maps. Section lines often run along county roads and are easily seen from the air. We assumed that deer densities were related to the amount of forest cover available and used the percent forest cover to stratify the quadrats. Percent forest cover in each quadrat was determined from the topographic maps and digitized into a mainframe Intergraph to calculate percent forest cover. Current aerial photographs were used to verify and correct U.S. Geological Survey woodlot data. Quadrats were grouped according to percent forest cover into three strata: low (0-9%), medium (10-19%), and high (20-100%). The boundary limits of the strata were set to reflect the range of available percent forest cover present in quadrats (*e.g.*, percent forest cover per quadrat ranged from 0% to 81% and averaged 18% for Steuben and ranged from 0% to 46% and averaged 11% for Marshall County). Optimum allocation was used to determine the number of quadrats selected for censusing among strata (Siniff and Skoog, 1964). Optimum allocation requires more sampling effort in the strata containing more variation (*i.e.*, more sampling was done in the quadrats with more variation in forest cover). Quadrats to be sampled were selected randomly. If a selected quadrat fell within an incorporated town, it was deleted and another quadrat was selected.

A 4-passenger Jet Ranger helicopter flown at an altitude of 60 to 100 m at 35-75 km/hr was used to conduct the surveys. To insure complete quadrat coverage, at least four transects, approximately 406 m apart, were flown. Search time per quadrat varied from 5 to 10 minutes and was concentrated over forested areas. The crew consisted of a pilot, navigator, and two observers. The navigator not only was responsible for directing travel so as to decrease flight time between sampling units but also for assisting in locating groups of deer. Observers, seated on opposite sides of the helicopter, were in continuous audio contact and were responsible for counting the number of deer seen within 203 m (666 ft) of the flight line. The helicopter conducted turns at the end of each transect so that the inside observer could maintain visual contact with any deer seen. To avoid recounting deer, the observers relayed number of deer and their position in the quadrat to each other. The total number of deer in each quadrat was the sum of deer from each observer's independent count corrected for those deer seen by both observers.

Aerial censuses were conducted when snow cover was greater than 8 cm and weather conditions provided clear visibility. The accuracy of the aerial surveys was checked by ground counts. Random selection of woodlots for ground truthing was not practical because of problems in obtaining authorized access. The number of woodlots ground truthed in each County was limited by the number of woodlots that could be censused in one day. Woodlots for ground truthing were not selected based on their habitat characteristics or ease of aerial surveying

but solely on their isolation from adjoining census quadrats, ease of access, and their overall configuration and size. Isolation of woodlots from adjoining census quadrats was important to avoid movement of deer from a ground count woodlot into quadrats that were to be aerially censused later. A ground crew was in position at the woodlot before the helicopter arrived. After the helicopter count, the drivers began their count and the helicopter took up a position that allowed its occupants to watch for deer leaving the area. Drivers, spaced not more than 20 m apart, walked through woodlots while blowing whistles and shouting to encourage the deer to flee. The drivers maintained a straight line by radio communication and counted deer that passed back through the line between them and the person to their right. Counters positioned at the sides and end boundaries of the woodlot counted all deer that fled the area ahead of the progressing drive line. Comparing ground counts with aerial counts provided an estimate of aerial count accuracy and allowed for calculation of a sightability correction factor.

Statistical Methods. Differences in mean deer densities within strata by time of day and among days were analyzed using Duncan's Multiple Range Test ($\alpha = 0.05$; SAS, 1988). Pearson's coefficient of correlation was used to evaluate the relationship between percent forest cover and deer density. Deer population estimates were calculated using the procedures outlined by Cochran (1977) and Davis (1982) and illustrated by Siniff and Skoog (1964) and Gasaway, *et al.* (1986) for stratified random sampling; allocation of sampling was optimized using Neyman allocation (Cochran, 1977).

RESULTS

Aerial Surveying. In Steuben County, 51 quadrats out of a possible 108 in the high stratum, 20 of 130 in the medium, and 10 of 82 in the low were selected for censusing. In Marshall County, 25 of 46 quadrats in the high stratum, 30 of 132 in the medium, and 55 of 263 in the low were selected for censusing.

In 1990, inadequate snow cover in Marshall County prevented aerial censusing. Aerial censusing in Steuben County was conducted on three days in February. Snow depth on the first day was acceptable, but snow-cover conditions deteriorated with each successive day so that by the third day bare ground was visible in the open fields. A total of 77 quadrats (24% of the County) was censused. The number of quadrats censused for the high, medium, and low strata were 48, 19, and 10, respectively. A total of 1,743 deer was observed. The high stratum had a greater mean number of deer per hectare than the other strata; the low stratum had a higher mean than the medium stratum (Table 1). Variance within strata was mixed, but only in the low stratum was the variance significantly different between days; the variance increased with each successive day of censusing as snow cover declined. The mean number of deer seen also decreased with declining snow cover.

In the winter of 1991, weather conditions allowed censusing of 25% of both Steuben and Marshall Counties. Portions of Marshall County were surveyed

Table 1. Summary data from aerial censuses of white-tailed deer in Steuben and Marshall Counties, Indiana, in the winters of 1990 and 1991.

County, Year	Stratum	Number of % Quadrats Censused	Forest Cover / ha		Deer / ha	
			$\bar{X}$	SE	$\bar{X}$	SE
Steuben, 1990	High	48	29.37	0.013	0.0991	0.0192
	Medium	19	15.74	0.006	0.0624	0.0163
	Low	10	7.04	0.004	0.0819	0.0275
Marshall, 1991	High	25	28.52	0.015	0.0907	0.0218
	Medium	30	14.62	0.006	0.0576	0.0095
	Low	55	5.77	0.003	0.0237	0.0048
Steuben, 1991	High	51	30.02	0.013	0.1014	0.0137
	Medium	20	15.58	0.006	0.0948	0.0257
	Low	10	6.74	0.005	0.0375	0.0180

on five days in January. Snow conditions did not allow surveys to be conducted on consecutive days. A total of 1,372 deer was observed in Marshall County. Steuben County was surveyed on 31 January and 1 February by flying the same quadrats as in 1990, and 1,927 deer were observed. For both Counties in 1991, the high strata had the highest mean number of deer, and the medium strata had a higher number than the low strata (Table 1). Further, no significant differences in number of deer was seen between days or between morning and afternoon surveys.

Percent forest cover was significantly correlated ($r = 0.33$, $P < 0.001$) with the number of deer counted in each quadrat. In Steuben County, r was 0.21 in 1990 ($P = 0.034$) and 0.24 in 1991 ($P = 0.016$). In Marshall County in 1991, r was 0.41 ($P < 0.001$).

Ground Counts. Ground counts were conducted in five woodlots in Steuben County on 27 February 1990 and in six woodlots on 31 January 1991 with a ground crew of 14 and 13 people, respectively. Helicopter observers missed 3 of 100 deer in 1990 and 16 of 123 deer in 1991. Ground counts were conducted in four woodlots in Marshall County on 24 January 1991 by a crew of 16 people. The same number of deer was counted by both helicopter and ground surveys. Combining the ground counts for both Counties resulted in an average accuracy of 93% and a correction factor of 1.08 for aerial counts.

Population Estimation. The County population estimate was calculated by multiplying the sum of the weighted, stratified means per quadrat by the total number of quadrats in the County (Burgdorf, 1991). The sightability correction factor was calculated by combining the ground counts from both Counties.

Surveys conducted in Steuben County in 1990 resulted in a population estimate of 6,678 deer, which, when multiplied by the combined sightability cor-

Table 2. Comparison of white-tailed deer population estimates calculated from aerial censuses and by the sex-age-kill method in Indiana in 1990-1991.

County, Year	Preharvest Sex-Age-Kill Population Estimate	Legal Harvest	Adjusted Sex-Age-Kill Population Estimates	Aerial Census Population Estimates (95% C.I.)
Steuben, 1990	9,456	2,818	6,638	7,212 ($5{,}550 < \bar{x} < 8{,}924$)
Marshall, 1991	7,114	2,180	4,934	5,005 ($4{,}136 < \bar{x} < 5{,}874$)
Steuben, 1991	8,143	2,892	5,251	7,436 ($5{,}601 < \bar{x} < 9{,}271$)

rection factor (1.08), yielded a corrected, total estimated posthunt, prior to recruitment, deer population for Steuben County (Table 2) of 7,212 deer or 0.09 deer/ha total area (0.04/ac). The 95 percent confidence interval was 7,212 ± 1,712 deer. In 1991, aerial surveys in Steuben County resulted in a posthunt deer population estimate of 6,886 deer, which yielded in a total corrected population estimate of 7,436 deer or 0.09 deer/ha total area (0.04/ac). The 95 percent confidence interval was 7,436 ± 1,835 deer. Aerial surveying in Marshall County in 1991 resulted in a posthunt deer population estimate of 4,635 deer and a corrected total posthunt population estimate of 5,005 deer or 0.04 deer/ha total area (0.02/ac). The 95 percent confidence interval was 5,005 ± 869 deer.

To compare the posthunt deer density estimates from the aerial surveys with the preharvest sex-age-kill estimates, the number of deer harvested in the County was subtracted from the preharvest sex-age-kill estimate. The deer density estimates calculated for Marshall and Steuben Counties from aerial surveys compare closely with the Indiana Division of Fish and Wildlife's sex-age-kill estimates (Table 2).

DISCUSSION

We decided to census 25% of each county based on the results of other studies. Beasom, *et al.* (1986) investigated the accuracy and precision for different sampling intensities in a mesquite-mixed brush habitat in Texas and found that sampling intensity did not significantly affect the mean percentage of deer observed (similar means were observed at 100% sampling intensity as at 50% and 25%). The resulting variance for deer observed in smaller samples was somewhat larger than for total coverage of the area but not large enough to justify the increased cost of helicopter time (Beasom, *et al.*, 1986). Evans (1975) suggested that a negative bias in the total number of deer seen results when the sampling intensity increases above 25% of the area.

In an effort to decrease variance among sample areas and optimize flight time, we followed the examples of Siniff and Skoog (1964) and Gasaway, *et al.* (1986) for stratified random quadrat sampling with optimal allocation (Neyman allocation). Stratification groups the more homogeneous quadrats together so that within strata variances are relatively small (Siniff and Skoog, 1964; Gasaway, *et al.*,1986). Knowledge of the total possible number of quadrats grouped in each stratum and the variance within each stratum is essential to allocating sampling effort optimally. Frequently, estimates of relative density will approximate measures of relative variance. Because we lacked knowledge of deer density distributions in the Counties, we need a measure of relative habitat suitability as a surrogate measure of relative variance (Gasaway, *et al.*,1986). Although deer in Indiana do not usually exhibit yarding behavior in winter, they do gather in small herds of 20 or so animals and tend to frequent forested areas or other vegetative cover (Mumford and Whitaker, 1982). Optimum allocation, which requires more sampling effort in the strata containing more variation, was used to determine the number of quadrats selected for censusing among strata (Siniff and Skoog, 1964; Cochran, 1977). During the 1990 winter survey in Steuben County, a large number of deer were observed in low stratum quadrats on the third day, presumably because of a lack of snow in the open fields while snow cover still existed in the woodlots. This large number of deer using open fields was contrary to the assumption that deer would seek shelter in the woodlots and affected the mean number of deer calculated for the low stratum in Steuben County in 1990.

In aerial surveys, visibility bias resulting from the failure to observe all animals is considered the primary source of error (Samuel and Pollock, 1981). Many factors, such as weather, terrain, vegetation, and pilot/observer fatigue, can exacerbate the inherent visibility bias of aerial counts (Siniff and Skoog, 1964; Pollock and Kendall, 1987). In the brush-covered rangelands of Texas, Beasom, *et al.* (1986) found that helicopter surveys of white-tailed deer were 26-40% accurate. In large enclosures of snow-covered pinyon (*Pinus edulis*)-juniper (*Juniperus osteosperma*) woodlands in Colorado, between 60% and 68% of the mule deer (*Odocoileus hemionus*) were seen during helicopter counts (Bartmann, *et al.*, 1986). Rice and Harder (1977) conducted a mark-recapture study with helicopter surveys of white-tailed deer and found that accuracy ranged from 51% to 70% of the animals known to be present (127/km^2) in a 122-ha enclosure in northern Ohio with snow present on the various brush, field, and hardwood habitat types. In western Ohio, where forested area ranged between 4% and 14% and deer densities ranged between 2 and 5 deer/km^2, helicopter counts were 99% accurate (Stoll, *et al.*, 1991). The Ohio study is the one most similar to ours in the amount of forest cover, snow cover, terrain (predominantly level) , woodlot size (small), and deer densities (low). As Stoll, *et al.* (1991) stated, this combination of factors is probably what allows aerial censusing to achieve such high accuracy. The accuracy of our aerial survey ranged from 86% to 100%. The accuracy of the aerial counts was affected by the incomplete

coverage and duration of the snow cover, especially during the first winter. A mottled background, caused by the lack of complete snow cover, makes observations more difficult and, therefore, less accurate (Siniff and Skoog, 1964).

The ground counts were a reliable check of the helicopter surveys. Although our woodlots were not chosen randomly, they were chosen without knowledge of habitat structure (*e.g.*, ease of visibility was not a factor in the selection process). Some important rules for the drive-line censusing of deer are: 1) the understory and terrain of the area must allow for optimal viewing between drivers; 2) persons in the drive line must be sufficiently close together; and 3) the line must be kept straight (deCalesta and Witmer, 1990). Recommended between-driver distances are 40 m (Hosely, 1936), 15-30 m (Trippensee, 1948), and 22 m (deCalesta and Witmer, 1990). The personnel manning our drive lines were less than 20 m apart and maintained a straight line through the sparse understory by using radio headsets for communication. Woodlots censused ranged from 9 to 28 ha in size. The small woodlot size, level terrain, sparse understory vegetation, adequate personnel, and snow-covered fields as boundaries allowed for reliable ground counts of the deer. Although the potential existed for missing deer (*e.g.*, those that remained bedded), we believe this bias was small.

The correction factor for forested areas was applied to the total deer estimate calculated from the aerial counts. The correction factor was not applied to the mean number of deer in only the high and medium forest cover quadrats; it was also applied to the low forest cover quadrats. Even though many deer were counted in the open fields of Steuben County in 1990, the sightability correction factor was used. The sightability correction factor was low enough that it did not substantially inflate deer population estimates.

Deer density in each stratum was closer to the anticipated pattern (high stratum > medium stratum > low stratum) in 1991 than in 1990, possibly due to better snow cover and the increased experience of both the observers and pilots. LeResche and Rausch (1974) found that experienced observers saw significantly more deer than did inexperienced observers.

In both Counties, a positive correlation existed between percent forest cover and deer density, although the coefficient of correlation was low. This correlation suggests that forest cover alone does not necessarily reflect deer presence. Individual forest stands vary in quality as deer habitat; other habitats, such as Conservation Reserve Program lands, may also be used by deer in winter. Steuben County has more than 11,000 ha (27,000 ac) registered in the Conservation Reserve Program compared to 1,994 ha (4,927 ac) in Marshall County. According to Indiana Division of Fish and Wildlife biologists, Conservation Reserve Program lands are important habitat for deer in winter. Lack of Conservation Reserve Program lands in Marshall County might be the reason for the lower variances in the numbers of deer per quadrat calculated for all strata in Marshall County in contrast to the higher variances in Steuben County. The presence of Conservation Reserve Program land was not considered during stratification within Counties. Including Conservation Reserve Program lands in the

stratification process could improve mean estimates by decreasing the variance within strata.

Linear fence rows and roads, generally with north-south and east-west orientations, helped distinguish the boundaries of quadrats so that their limits could be ascertained. Care was taken not to count deer outside the quadrat boundary lines, but a source of error was the inability of observers to accurately count large groups of animals. Large herds were circled with the helicopter in a clockwise manner so that the navigator and one observer were able to simultaneously count until their counts agreed or the deer groups dispersed. Other factors also affected deer presence or absence in woodlots—the presence of free-roaming dogs, recent timber harvests, and the juxtaposition of the woodlots to urbanized areas. However, these factors were not sufficiently monitored to allow evaluation of their effects in this study.

The total deer population estimates calculated for Marshall and Steuben Counties by the Indiana Division of Fish and Wildlife's sex-age-kill method are similar to the estimates generated by the aerial surveys. Posthunt estimates from preharvest sex-age-kill estimates are likely overestimates of population size, because the crippling loss and nonharvest mortality numbers are not known and are not subtracted from the preharvest sex-age-kill estimates. Helicopter surveys, on the other hand, tend to underestimate deer populations and thus the need for correction factors. Deer population estimates from the sex-age-kill method for Steuben County (1990) and Marshall County (1991) fall within the 95% confidence intervals of the aerial survey estimates. The estimate obtained from the aerial survey of Steuben County in 1991 is higher and does not contain the sex-age-kill estimates within its 95% confidence interval. Change in the rate of population increase could be influenced by the rate of hunting pressure or the effect of weather conditions on the number of deer harvested in 1990. For example, one of the assumptions of the sex-age-kill method is that the annual buck harvest (hunting pressure) is consistent from year to year. Since all assumptions for the sex-age-kill method cannot be fully met, the method may be subject to error. The ability of the sex-age-kill model to reflect yearly variations in hunting pressure and population fluctuations in Indiana should be investigated further.

CONCLUSIONS

Use of forest cover percentage as a surrogate for deer density in the stratification of the Counties may have resulted in lower variances within strata; however, an improved method of stratification (*i.e.*, including other habitat types such as Conservation Reserve Program land) may be more helpful in future surveys. The relatively high accuracy of our helicopter counts can be attributed to the combination of low deer densities, small woodlot size, hardwood stands with virtually no conifers, sparse understory, and open snow-covered fields surrounding woodlots. The sightability correction factor calculated for Marshall and Steuben Counties would not be a valid correction factor for all Indiana counties, because

the habitat and terrain of southern and northern Indiana differ greatly. Marshall and Steuben Counties are more similar to each other than either is to the more forested and hilly terrain common in southern Indiana.

To improve future aerial surveys, we offer a number of recommendations: 1) surveys should be conducted on consecutive days of complete snow cover to decrease the chances of human activities causing deer herd movements between adjacent, counted versus uncounted, quadrats; 2) the acreage of Conservation Reserve Program lands, classified wildlife areas, and so forth, should be considered in stratification; 3) to improve stratification, a nearest-neighbor rating for each quadrat based on the habitat available in adjoining quadrats should be incorporated; 4) practice counts should be made each year in another area prior to starting the actual survey to allow crew members to gain experience; 5) yearly aerial surveys should be conducted during adequate snow cover to investigate the effect of increased harvest rates on population estimates; and 6) the number of ground truth counts should be increased to better measure accuracy.

Aerial surveys produced reliable estimates of deer density in Marshall and Steuben Counties and corresponded well with the estimates made using the sex-age-kill method. Still, the inputs for the sex-age-kill model need to be refined and verified by additional population studies.

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