ESTIMATING WHITE-TAILED DEER ABUNDANCE USING AERIAL QUADRAT SURVEYS

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SUMMARY OF FINDINGS

I estimated white-tailed deer (*Odocoileus virginianus)* abundance in select permit areas (PA) using stratified random and 2-dimensional systematic quadrat surveys to recalibrate deer population models and evaluate the impact of deer season regulation changes on population size. With rare exception, precision of population estimates was similar among permit areas. However, because population estimates were not corrected for sightability, estimates represent minimum counts and are biased low. Beginning in 2009, I will begin to develop a sightability estimator to adjust estimates for animals missed during surveys.

INTRODUCTION

Management goals for animal populations are frequently expressed in terms of population size (Lancia et al. 1994). Accurate estimates of animal abundance allow for documentation of population trends, provide the basis for setting harvest quotas (Miller et al. 1997), and permit assessment of population and habitat management programs (Storm et al. 1992).

The Minnesota Department of Natural Resources (MNDNR) uses simulation modeling to estimate and track changes in deer abundance and, subsequently, to develop harvest recommendations to keep deer populations within goal levels. In general, model inputs include estimates of initial population size and spatial/temporal estimates of survival and reproduction for various age and sex cohorts. Because simulated population estimates are subject to drift as model input errors accumulate over time, it is imperative to periodically recalibrate the starting population within these models with independent deer population estimates (Grund and Woolf 2004).

Minnesota's deer numbers are managed according to numeric population goals within 125 PAs. MNDNR recently revised deer population goals within each PA using a consensus-based, round–table approach consisting of 15-20 citizens representing varied interest groups (e.g. deer hunters, farmers, foresters, environmental groups, etc.; Stout et al. 1996). Revised goals are used to guide deer-harvest recommendations. Currently, deer populations exceed management goals in many PAs. A conventional approach of increasing the bag limit within the established hunting season framework has failed to reduce deer densities. As a result, MNDNR has begun testing the effectiveness of 3 non-traditional harvest regulations to increase the harvest of antlerless deer and reduce overall population levels (Grund et al. 2005). Accurate estimates of deer abundance are needed to evaluate these regulations.

My objective in this investigation is to provide independent estimates of deer abundance in select PAs that are within 20% of the true mean with 90% confidence (Lancia et al. 1994). Abundance data will be used to recalibrate population models to improve population management and to evaluate impacts of deer season regulation changes on deer abundance.

METHODS

I estimated deer populations in selected PAs using a quadrat-based, aerial survey design. Quadrat surveys have been used to estimate populations of caribou (*Rangifer tarandus*; Siniff and Skoog 1964), moose (*Alces alces*; Evans et al. 1966), and mule deer (*O. heimonus*; Bartmann et al. 1986) in a variety of habitat types. I employed a stratified, random sampling design, with quadrats stratified into 2 abundance classes (low, high) based on relative deer densities, in PAs where the local wildlife manager had prior knowledge about deer abundance and distribution. In other areas, I used a 2-dimensional systematic sampling design (Cressie 1993, D'Orazio 2003). Systematic designs are typically easier to implement, maximize sample distribution, and are often more efficient than simple or stratified random sampling designs (Cressie 1993, D'Orazio 2003).

Within each PA, quadrats were delineated by Public Land Survey section boundaries and a 20% sample was selected for surveying. Sample size calculations indicated this sampling rate was needed to meet accuracy and precision objectives. I excluded quadrats containing navigation hazards or high human development, and selected replacement quadrats in stratified PAs. Replacement quadrats were unavailable in the systematic PAs because of the rigid, 2-dimensional design. I used OH-58 helicopters during most surveys. A Cessna 182 airplane was used in 3 PAs dominated by intensive row-crop agriculture. To increase visibility, I completed surveys after leaf-drop and when snow cover measured at least 15 cm. A pilot and 2 observers searched for deer along transects spaced at 270-m intervals until they were confident all deer were observed. I used a real-time, moving-map software program (DNR Survey; MNDNR 2005), coupled to a global positioning system receiver and a tablet-style computer, to guide transect navigation and record deer locations and aircraft flight paths directly to ArcView GIS (Environmental Systems Research Institute 1996) shapefiles. I estimated deer abundance from stratified surveys using SAS Proc SURVEYMEANS (SAS 1999) and from systematic surveys using formulas developed by D'Orazio (2003). I evaluated precision using coefficient of variation (CV), defined as standard deviation of the population estimate divided by the population estimate, and relative error (RE), defined as the 90% confidence interval bound divided by the population estimate (Krebs 1999).

RESULTS AND DISCUSSION

I completed 5 surveys during January-February 2005, 8 surveys during January-March 2006, 7 surveys during January-March 2007, and 4 surveys during December 2007-February 2008 (Table 1). Stratified fixed-wing surveys were conducted in PAs 421 and 423. Based on long-term deer harvest metrics, population estimates in these areas were biased low. Several possibilities may explain this result: 1) deer were clustered in unsampled quadrats; 2) deer were wintering outside PA boundaries; 3) sightability was biased using fixed-wing aircraft; and/or 4) kill locations from hunter-killed deer were reported incorrectly. Land cover in these PAs was dominated by intensive row-crop agriculture. After crops were harvested each fall, deer habitat was limited to riparian areas, wetlands, abandoned farm groves, and undisturbed grasslands, including those enrolled in state and federal conservation programs. Although recreational feeding of deer could influence distribution, wildlife managers believed it was not a common practice in these PAs. Thus, I had no evidence to support non-traditional deer distribution in these units. I also had no reason to believe hunter registration errors had greater bias in these units than in other PAs. Although it was possible that deer occupied unsampled quadrats by chance, the use of optimal allocation to increase sampling effort in high strata plots because of expected higher deer densities should minimize this possibility. Furthermore, we surveyed 100% of the high-strata plots in PA 421, resulting in no unsampled quadrats. Sightability bias, however, is greater in fixed-wing aircraft than helicopters (LeResche and Rausch 1974, Kufeld et al. 1980, Ludwig 1981) and likely explained much of the bias I observed in these PAs. Consequently, all surveys have subsequently been conducted using a helicopter.

With the exception of PAs 421, 423, and 201, precision (CV, RE) of the population estimates was similar among PAs (Table 1). High precision in PA 421 was, in part, an artifact of sample design. Based on optimal allocation formulas, we selected and surveyed all high strata quadrats. Thus, because no sampling occurred within the high stratum (100% surveyed), sampling variance was calculated only from low strata quadrats. We observed few deer in these low strata quadrats, which resulted in low sampling variance and high precision of the population estimate. It is unlikely that this design (i.e., sampling 100% of high strata quadrats) will be feasible in all areas, especially if deer are more uniformly distributed throughout the landscape.

In contrast, survey precision in PAs 423 and 201 was poor. We observed few deer during either survey (*n*=144 and 56, respectively) and nearly all observations occurred within 1 or 2 quadrats. As a result, associated confidence intervals exceeded 60% of the population estimate (Table 1). Kufeld et al. (1980) described similar challenges with precision due to nonuniformity of mule deer distribution within strata in Colorado.

I did not correct population estimates for sightability. Thus, estimates represent minimum counts and are biased low. Although sightability correction factors for deer are available in the literature (Rice and Harder 1977, Ludwig 1981, Stoll et al. 1991, Beringer et al. 1998), I believe it would be inappropriate to apply them to our survey areas because of differences in sampling design and habitat characteristics. Beginning in 2009, I will attempt to develop a sightability estimator to adjust for animals missed during surveys. This estimator will improve population estimates by reducing visibility bias. Future analysis will also include *post-hoc* evaluation of habitat features present in quadrats containing deer. This will provide additional empirical data for use in quadrat stratification. In addition, the impact of winter feeding on deer distribution will be examined to determine if pre-survey stratification flights (Gasaway et al. 1986) are warranted.

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Table 1. Deer population and density estimates derived from aerial surveys in Minnesota, 2005-2008.

Sampling design	Year	Permit area	Population estimate *N*	Population estimate 90% CI	CV (%)	Relative error (%)[a]	Density estimate (deer/mi^2) Mean	Density estimate (deer/mi^2) 90% CI	Model estimate (deer/mi^2)
Systematic	2005	252	2,999	2,034 – 3,969	19.5	32.2	2.9	2.0 – 3.9	2
		257	2,575	1,851 – 3,299	16.9	28.1	6.2	4.4 – 7.9	7
	2006	204	3,432	2,464 – 4,401	17.0	28.2	4.6	3.3 – 5.9	5
		209	6,205	5,033 – 7,383	11.4	18.9	9.7	7.9 – 11.5	5
		210	3,976	3,150 – 4,803	12.5	20.8	6.3	5.0 – 7.6	7
		256	4,670	3,441 – 5,899	15.9	26.3	7.1	5.3 – 9.0	5
		236	6,774	5,406 – 8,140	12.1	20.2	16.8	13.4 – 20.2	37
	2007	225	5,341	4,038 – 6,645	14.7	24.4	8.0	6.0 – 9.9	24
		227	5,101	4,245 – 5,960	10.1	16.8	9.8	8.2 – 11.5	13
		346	7,896	5,736 – 10,062	16.4	27.4	22.7	16.5 – 29.0	31
	2008	265	4,575	3,766 – 5,384	10.7	17.7	9.2	7.6 – 10.9	n/a[b]
		266	3,853	2,733 – 4,977	17.5	29.1	6.2	4.4 – 8.0	n/a[b]
Stratified	2005	206	2,486	1,921 – 3,051	13.7	22.5	5.2	4.0 – 6.4	5
		342	3,322	2,726 – 3,918	10.8	17.7	9.1	7.5 –10.7	10
		421	631	599 – 663	3.0	5.0	0.8	0.8 – 0.9	5
	2006	201	274	100 – 449	37.6	61.9	1.6	0.6 – 2.7	6
		420	1,740	1,301 – 2,180	15.2	25.1	2.6	2.0 – 3.3	3
		423	472	179 – 764	37.4	61.5	0.9	0.3 – 1.4	5
	2007	343	6,982	5,957 – 8,006	8.9	14.6	10.1	8.6 – 11.6	29
		344	4,116	3,375 – 4,857	10.7	17.7	19.7	16.1 – 23.2	49
		347	5,482	4,472 – 6,492	11.1	18.2	12.6	10.3 – 14.9	13
		349	10,103	8,573 – 11,633	9.1	15.0	20.4	17.3 – 23.5	35
	2008	422	1,019	848 – 1,189	10.1	16.6	1.6	1.3 – 1.8	8
		262	2,065	1,692 – 2,437	10.9	17.9	3.0	2.5 – 3.6	n/a[b]

[a]Relative precision of population estimate. Calculated as 90% CI bound ⁄ *N*.
[b]Permit area boundaries were recently modified. No model estimate is available