APPENDIX A

WINTER DENSITIES AND DISTRIBUTION OF DEER AND MOOSE IN NORTHEASTERN MINNESOTA

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Abstract: An aerial census for deer (Odocoileus virginianus) and moose (Alces alces) was completed in the winter of 1977-78 in northeastern Minnesota. A stratified random sampling technique with optimal allocation of sample plots was used. Uncorrected census results were 0.8 deer and 0.1 moose per square kilometer. The accuracy of the census was improved for deer by estimating numbers of animals missed within census plots. Moose results were adjusted using values from the literature. Corrected results are 2.3 deer and 0.3 moose per square kilometer. Deer and moose distributions were determined from aerial transects flown prior to the census. Distribution patterns and population densities may not be valid for times of the year other than the census period because of seasonal habitat changes.

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This census is part of an environmental impact statement on copper-nickel mining being prepared by the Minnesota Environmental Quality Council. The 1542 square kilometer area is located in northeastern Minnesota between the City of Ely and the City of Hoyt Lakes. It includes portions of Townships 57, 58, 59, 60, 61 and 62 North in Ranges 10, 11, 12, 13 and 14 West (Figure 1). Figures 2 and 3 illustrate by sections what areas are included.

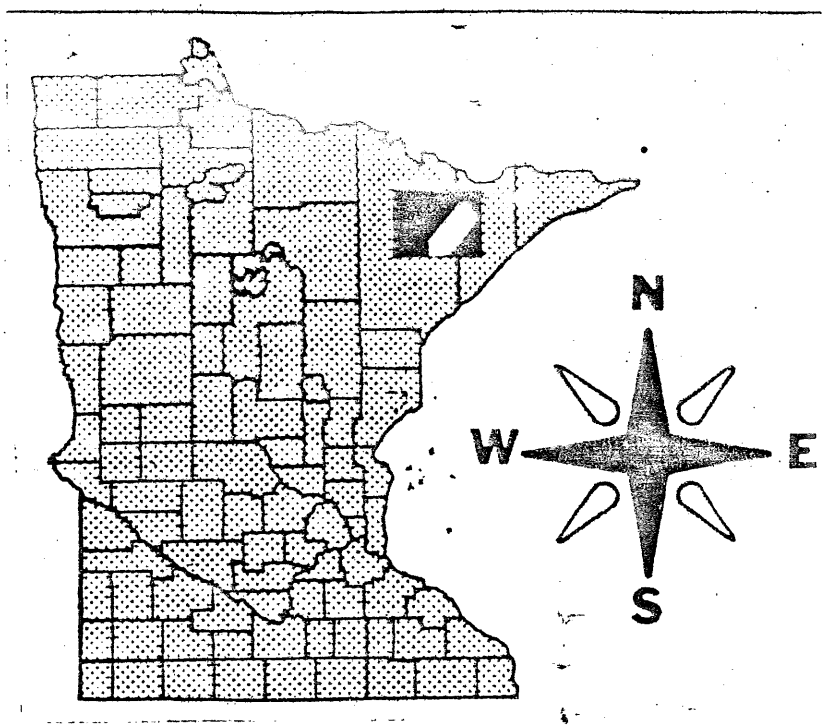


Figure 1. The study area

I wish to thank Dick Hempfner, Mark Kortkamp and Steve Knick for their assistance.

METHODS

The 1977-78 deer-moose aerial census was designed and analyzed according to criteria established by Cochran (1967) for stratified random samples with optimal allocation. Several studies used this technique to advantage in estimating big game populations (Bell et al. 1973, Eberhardt 1957, LeResche and Rausch 1974, Ryell 1960, Peek 1971, Siniff and Skoog 1964). Big game populations often occur in clumped distributions so stratified random sampling is particularly applicable to them. The basic objective in stratified random samples is to define strata which are relatively homogeneous. A stratum is a geographical area with a homogeneous density of animals. Thus precise estimates of stratum means can be obtained with smaller sample sizes and variances than with other sampling methods.

Defining strata requires prior knowledge of distributions and densities of the population.

After strata have been defined, sample sizes must be allocated for each stratum. Cochran (1967) defines two types of sample allocation: proportional and optimal. Optimal allocation is desirable when large differences exist between stratum means and is made proportional to both the stratum area and its variance. This requires knowledge of strata variances prior to the census. Often variances are not known and other estimates must be substituted. Population estimates can serve this purpose with the assumption that differences in strata densities reflect, in roughly the same proportions, the difference between strata variances.

Strata were defined from deer and moose distribution observed from the air along transects 2.6 kilometers (one mile) apart. Transect flights proceeded in a north-south direction. Trails and sightings of moose and deer were plotted on topographic maps by an observer watching from one side of the plane.

Transect data also provided the data for optimally allocating sample plots within strata. Previous studies (Bell et al. 1973, Peek 1971, Siniff and Skoog 1964) had established that estimates of strata densities could be successfully substituted for strata variances. The census design used here assumed that numbers of animals and trails, recorded from transects, within strata would be equally effective in reflecting strata variances. Table 1 illustrates the necessary computations for optimally allocating plots among strata.

Sample plots were approximate square miles (2.6 square kilometers) with boundaries based on identifiable geographic landmarks where possible. Unlike plots based on a grid system, boundaries easily identified from the air reduced the possibility of mistakenly counting animals which may or may not have been in the plot.

Census flights were begun on the 28th of December and completed on the 16th of March. Eighty plots were intensively searched at altitudes of from 60 to 150 meters (200 to 500 feet) above ground with a Piper PA-18A-150 Super Cub. Plots were searched in a series of overlapping circles so that each piece of ground was observed at least once. Both pilot and passenger functioned as observers. When deer or moose were sighted, the pilot was requested to circle until observers were satisfied that as many animals as possible were counted.

RESULTS AND DISCUSSION

Deer-Moose Distribution

Deer distribution was classified as high, medium, and low density range (Figure 2.). Moose distribution was classified as high and low density (Figure 3.). Data needed to stratify the areas in figures 2 and 3 were gotten from recording trails and animals sighted during transect flights. Comparison of figures 2 and 3 reveals little overlap between high density deer and moose range during winter.

High density deer range comprised 16% of the total area and contained 48% of all trails and animals observed. Medium density range occupied 21% of the area and included 24% of the trails and animals observed. The rest of the area (63%) was low density range which included 28% of all trail and animal observations. In census plots, 140, 29 and 36 deer were observed in high, medium and low density strata respectively (Table 3).

High density deer range was located along the southern shores of White Iron and Farm Lakes surrounding the Kawishiwi river area (Figure 2). It also included an area extending approximately eight miles southwest of Birch Lake and the City of Babbitt. A third area of high density range existed in the southern end of the study area south and southeast of Hoyt Lakes and north of the Whiteface Reservoir. Medium density deer range primarily occupied zones surrounding high density area in the northern half of the study area, while in the southern one-third it occupied most of the area. Nearly all of the area east of a line extending lengthwise northeast-southwest through the center of the study area was low density.

High density moose range was mostly confined to the northeast one-third of the study area. A small portion was located about eight miles east of Hoyt Lakes (Figure 3). It comprised 14% of the total area and contained 68% of the total moose trail and animal observations recorded during transect flights and 33% (Table 3) of all moose observed in census plots.

Deer-Moose Density

Deer and moose densities were determined similarly, the methodology of which is illustrated in Table 2. Table 3 presents results for both deer and moose. Appendix 1 presents initial plot data from which values in Table 2 and 3 were calculated. Plot densities ranged from zero to 14 deer and zero to five moose per plot. Eighty plots were sampled for deer and moose. For deer 20, 14, and 46 plots were optimally allocated for sampling in high, medium, and low density strata respectively (Table 1). For moose 21 of high and 59 plots of low density strata were allocated. Each plot averaged 20 minutes for completion. The average area per plot was 2.6 square kilometers (one square mile).

Of 205 deer observed, 140 (68%) were in high, 29 (14%) were in medium, and 36 (18%) were located in low density plots (Table 3). These values projected for each stratum result in uncorrected figures of 654, 267 and 299 deer in high, medium and low density strata respectively for an overall uncorrected estimate of 1,221 deer in 1542.4 square kilometers (595.5 square miles).

It is acknowledged that a number of factors affect the observability of animals in aerial censues (Norton-Griffiths 1976, Caughley et al. 1976, LeResche and Rausche 1974, Pennywick and Western 1972). Probably in this area the factor most affecting census accuracy is forest cover type. Deer in coniferous cover are easily missed. Floyd et al. (submitted and included as Appendix II) describe a technique for correcting deer census results in an area included in this census. We assumed the correction factor includes the overall effects of all types of biases encountered during the census. The method was followed in this census and a correction factor was applied to results listed in Table 3 for deer. With the observers used, approximately 34% of all deer in each plot were actually observed, resulting in a correction factor of 2.92 (the reciprocal of 34%),(Table 4).

The corrected population estimate for the study area is 3567.7 deer (Table 3). The corrected mean is 2.3 deer per square kilometer (6.0 deer per square mile).

A total of 30 moose were observed in 80 sample plots, 10 (33%) in high density and 20 (67%) in low density range. The uncorrected projected total is 217 moose in 1542 square kilometers (Table 3), 40 moose in high density and 177 in low density stratum.

It should be assumed that moose are subject to observability biases similar to deer, although not necessarily of the same magnitudes. A moose correction factor was not determined for this study using techniques described by Floyd et al. (submitted). Instead, in analyzing data presented by LeResche and Rausche (1974), I assumed that about 50% of all moose in plots were not observed. Thus uncorrected results in Table 3 were multiplied by two.

The corrected moose population estimate in 1542 square kilometers is 434 moose (Table 3). This results in a mean of 0.3 moose per square kilometer (0.7 per square mile).

Various studies, including research done in this area (Hoskinson and Mech, 1976, Nelson 1977), have shown that deer exhibit seasonal migration patterns and that summer and winter ranges may differ. Thus it should be assumed that results presented here reflect population densities and distribution of deer in their winter range and may not hold true for other times of the year. This census was not begun until after a sample of radio-monitored deer had settled on their winter range (Nelson, personal communication).

In northeastern Minnesota there is a lack of data on seasonal habits of moose. To my knowledge it is not known whether winter and summer ranges differ. I am assuming that, like deer, moose were present on their winter range when the census was made. Thus as is the case with deer, census results may not be valid during other times of the year.

FIGURES

TABLES

APPENDICES

Table 1. Example of computations required for optimally allocating sample size within strata. Taken from deer data.

Stratum Density	N	W	s	W s	W s as a proportion	Optimal allocation of sample units 1/
High	94.1	0.158	697	110.1	0.25	20
Medium	127.6	0.214	356	76.2	0.17	14
Low	373.8	0.628	404	253.7	0.58	46
Totals	595.0	1.000		440.0	1.00	80

Definitions:

N = Total number of possible sample units 2/ per stratum.

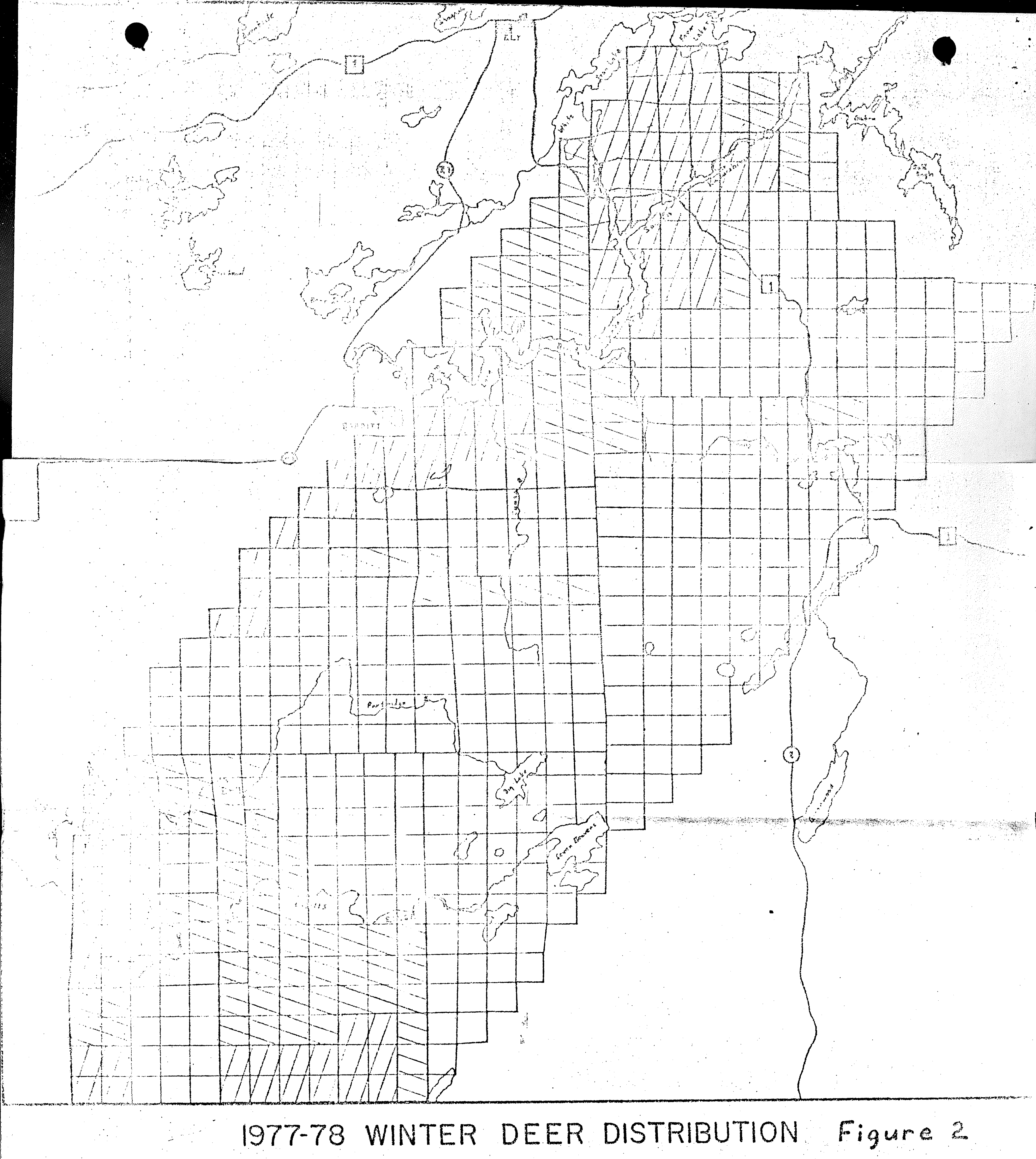
W = Proportion of possible sample units per stratum .

s = Number of trail and animal sightings within strata from transect data. Used in place of standard deviation.

W s = Product of W and s .

1/ Optimal allocation values represent the number of sample units chosen for the census (80) multiplied by W s as a proportion.

2/ A sample unit was one square mile (2.59 square kilometers).



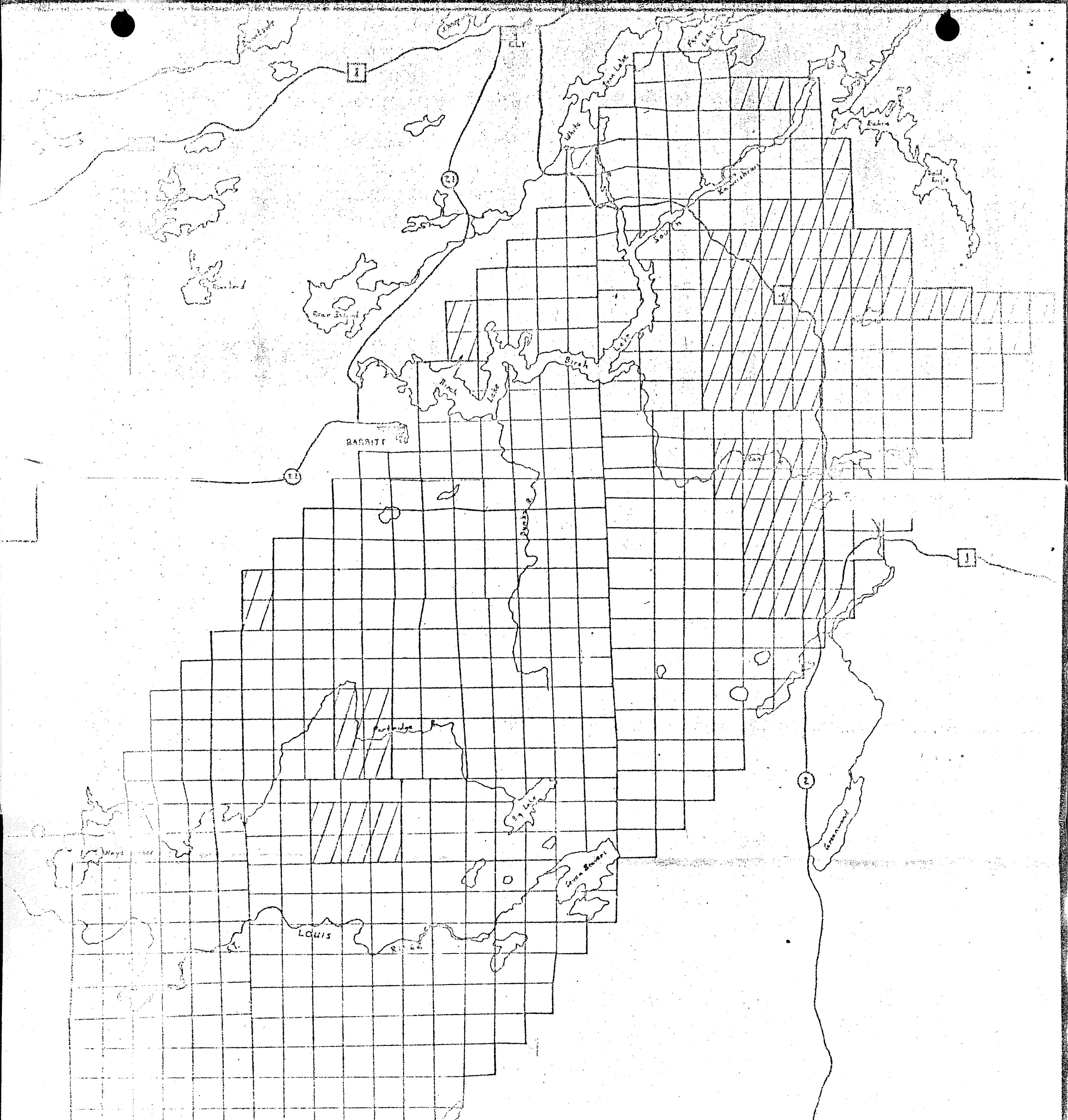
1977-78 WINTER DEER DISTRIBUTION *Figure 2*

- HIGH DENSITY
- MEDIUM DENSITY
- LOW DENSITY

1:126,720

0 1 2 3 4 5 10 MILES

0 1 2 3 4 5 10 20 KILOMETERS



1977-78 WINTER MOOSE DISTRIBUTION Figure 3

-HIGH DENSITY -LOW DENSITY

1:126,720

MILES
KILOMETERS

Table 2. Example of calculations required to derive a population estimate and variance. Taken from deer data.

Stratum Density	n	N	w	W	x	x	s^2	x /w	$(W^2 s^2/ n)(1-w)$
High	52.2	243.7	0.214	0.158	140	2.7	14.2	653.9	0.014
Medium	35.9	330.5	0.109	0.214	29	0.8	15.6	267.3	0.045
Low	116.5	968.2	0.120	0.628	36	0.3	2.7	299.3	0.020
Totals	204.6	1542.4		1.000	205			1220.5	0.079

Total population estimate X = (x /w) = 1220.5 deer

Population mean X = X /N = 0.8 deer/kilometer^2 (2.1 deer/mile^2)

Variance of the population estimate S^2 = $(W^2 s^2/ n)(1-w)$ 1/ = 0.079

Definitions:

- n = Amount of area (kilometers^2) sampled in each stratum.
- N = Amount of total area included in each stratum.
- N = Total area included in study area (N).
- w = Proportion of each stratum sampled (n /N).
- W = Proportion of area included in each stratum (N /N).
- x = Number deer observed per stratum.
- x = Sample mean number of deer per stratum (x /n).
- s^2 = Strata variance = $(x - x)^2/n - 1$.

1/ The quantity 1-w is a population correction factor which may be ignored if less than 0.1.

Table 3. Results of the 1977-78 deer-moose aerial census.

Density Strata	DEER: Area Counted Km²	DEER: Area Counted % of Stratum	DEER: Deer Seen No.	DEER: Deer Seen Per Km²	DEER: Projected Total	MOOSE: Area Counted Km²	MOOSE: Area Counted % of Stratum	MOOSE: Moose Seen No.	MOOSE: Moose Seen Per Km²	MOOSE: Projected Total
High	52.19	21.41	140	2.68	653.9	54.55	25.06	10	0.18	39.9
Medium	35.87	10.85	29	0.81	267.3	- 1/	-	-	-	-
Low	116.50	12.03	36	0.31	299.3	149.39	11.28	20	0.13	177.3
Totals	204.56		205		1220.5	203.94		30		217.2

DEER:

Correction factor 2/ x 2.92

Corrected total 3567.7

Deer/Km² 4/ 2.3

Deer/mile² 6.0

MOOSE:

Correction factor 3/ x 2

Corrected total 434.4

Moose/Km² 4/ 0.28

Moose/mile² 0.73

1/ The distribution and density of moose did not warrant a medium density stratum.

2/ From Table 4.

3/ A value chosen from LeResche and Rausch 1974.

4/ Study area was 1542.4 kilometers² (595.5 miles²).

Table 4. Results of deer observability tests.

Test Date	Weather 1/	Known No. of Collared Deer	No. Collared Deer Observed 2/	Percent Observed	Correction Factor 3/
February 21, 1978	Fair	11	1	9.1	
February 28, 1978	Fair	5	2	40.0	
March 10, 1978	Good	11	4	36.4	
March 24, 1978	Poor	11	6	54.5	
Totals		38	13	34.2	2.92

1/ Weather was poor when any of the following conditions prevailed: winds at 10 mph or above, temperature below -28°C, a low cloud cover or snow falling. When temperature was above -10°C, winds were light or calm, cloud cover was light, and there was no precipitation, conditions were considered good.

2/ Number of radio-tagged deer observed by both pilot and passenger.

3/ Reciprocal of percent observed.

APPENDIX I. Plot location and statistics.

Plot Location	Minutes for Completion	Area Km^2	MOOSE Stratum Density	MOOSE Number Observed	DEER Stratum Density	DEER Number Observed
T.62-R.11-Sec.3	21	2.1	Low	0	High	2
" " Sec.9	28	2.7	Low	2	High	0
" " Sec.17	26	2.2	Low	0	High	4
" " Sec.22	25	2.5	Low	0	High	7
T.62-R.12-Sec.25	17	2.3	Low	0	Medium	0
T.62-R.11-Sec.31	24	3.2	Low	0	High	6
" " Sec.35	30	2.7	Low	1	High	4
T.61-R.11-Sec. 5	20	2.4	Low	0	High	6
" " Sec. 1	18	2.7	High	5	Low	0
" " Sec. 7	21	2.9	Low	3	High	2
" " Sec. 9	24	2.7	Low	0	High	4
T.61-R.10-Sec. 7	16	2.5	High	0	Low	0
" " Sec.10	14	2.4	High	0	Low	0
" " Sec.17	25	2.8	High	0	Low	0
" " Sec.15	20	2.6	High	0	Low	0
" " Sec.13	22	3.2	High	0	Low	0
T.61-R. 9-Sec.17	17	2.9	High	3	Low	0
T.61-R.11-Sec.23	15	2.0	High	0	Low	0
T.61-R.12-Sec.25	24	2.8	Low	1	Medium	0
T.61-R.11-Sec.27	22	2.8	High	2	Low	0
" " Sec.25	15	2.6	High	0	Low	0
" " Sec.31	14	2.8	Low	3	Medium	0
T.61-R.10-Sec.31	23	2.6	High	0	Low	2
T.60-R.12-Sec. 2	21	2.5	Low	0	Medium	13
T.60-R.13-Sec.11	12	2.5	Low	0	High	9
T.60-R.12-Sec. 7	18	2.6	Low	0	High	14
T.60-R.11-Sec.10	20	2.6	High	0	Low	4
" " Sec.11	21	2.7	High	0	Low	0
T.60-R.10-Sec. 9	16	2.9	Low	0	Low	0
T.60-R.13-Sec.13	25	2.8	Low	0	High	9
T.60-R.11-Sec.15	18	2.7	High	0	Low	0

Plot Location	Minutes for Completion	Area Km^2	MOOSE Stratum Density	MOOSE Number Observed	DEER Stratum Density	DEER Number Observed
T.60-R.10-Sec.18	22	2.5	High	0	Low	0
T.60-R.13-Sec.21	31	2.6	Low	0	High	10
" " Sec.22	20	2.3	Low	0	High	9
T.60-R.12-Sec.21	19	2.5	Low	0	Low	0
" " Sec.24	15	2.6	Low	3	Low	0
T.60-R.13-Sec.29	27	2.9	Low	0	High	7
T.60-R.11-Sec.26	23	2.4	High	0	Low	6
" " Sec.35	20	2.6	High	0	Low	0
T.60-R.10-Sec.31	18	2.6	High	0	Low	3
T.59-R.12-Sec.4	21	2.2	Low	0	Medium	0
T.59-R.10-Sec. 6	23	2.4	High	0	Low	1
T.59-R.13-Sec. 8	20	2.3	Low	0	Low	0
" " Sec.11	17	2.3	Low	0	Low	0
T.59-R.12-Sec.12	21	2.2	Low	0	Low	0
" " Sec.18	30	3.4	Low	2	Low	4
" " Sec.13	19	2.7	Low	0	Low	0
T.59-R.13-Sec.22	19	2.4	High	0	Low	0
T.59-R.11-Sec.23	14	2.3	Low	0	Low	0
T.59-R.13-Sec.27	11	2.6	High	0	Low	0
T.59-R.12-Sec.28	16	2.3	Low	0	Low	0
T.59-R.14-Sec.35	20	2.6	Low	0	Low	1
T.58-R.12-Sec. 4	14	2.3	Low	0	Low	2
T.59-R.11-Sec.31	17	2.4	Low	0	Low	0
T.58-R.13-Sec. 5	20	2.3	Low	0	Low	7
T.58-R.12-Sec. 4	14	1.8	Low	0	Low	0
T.58-R.11-Sec. 5	17	2.0	Low	0	Low	0
T.58-R.14-Sec.11	20	2.3	Low	0	Medium	2
T.58-R.12-Sec.12	20	2.7	Low	0	Low	0
T.58-R.14-Sec.15	20	2.7	Low	0	Medium	2
" " Sec.13	25	2.9	Low	0	Medium	0
" " Sec.20	26	2.8	Low	0	High	14
" " Sec.23	20	1.6	Low	0	Low	2
" " Sec.24	18	2.2	Low	0	Medium	1

Plot Location	Minutes for Completion	Area Km^2	MOOSE Stratum Density	MOOSE Number Observed	DEER Stratum Density	DEER Number Observed
T.58-R.12-Sec.22	17	1.9	Low	0	Low	0
T.58-R.14-Sec.30	22	2.6	Low	0	High	8
" " Sec.31	23	2.7	Low	0	High	10
" " Sec.32	25	2.3	Low	0	High	10
" " Sec.33	21	2.5	Low	0	Medium	0
" " Sec.34	26	2.5	Low	0	Medium	9
T.58-R.13-Sec.36	15	2.5	Low	3	Low	2
T.57-R.13-Sec. 5	26	2.6	Low	0	Medium	0
T.57-R.12-Sec. 6	18	2.8	Low	0	Low	0
T.57-R.14-Sec. 9	21	2.6	Low	0	Low	0
T.57-R.13-Sec. 7	25	2.9	Low	0	Medium	2
T.57-R.12-Sec. 7	18	2.8	Low	0	Low	0
T.57-R.14-Sec.23	15	2.8	Low	2	Low	0
" " Sec.24	17	2.7	Low	0	Medium	0
T.57-R.12-Sec.19	22	2.8	Low	0	Low	2
T.57-R.14-Sec.36	24	3.0	Low	0	High	5
Totals	1624	204.4	80	30	80	205
Means	20	2.6	-	-	-	-

APPENDIX II

Floyd, T.J., L.D. Mech, and M.E. Nelson. 1978.
An improved method of censusing
deer in deciduous-coniferous forests.
Submitted - J. Widl. Manage.

AN IMPROVED METHOD OF CENSUSING DEER IN DECIDUOUS-CONIFEROUS FORESTS

Aerial censusing has been used to determine densities of many large mammals, including deer (Odocoileus virginianus) in agricultural areas or deciduous forests (Saugstad 1942, Morse 1946, Petrides 1953, Sanderson 1953, Berner pers. Comm.). However, observability of deer from the air remains a problem in northern coniferous forests. LeResche and Rausch (1974) determined that even with the much larger and more observable moose (Alces alces) during ideal snow conditions, experienced observers only counted 68 percent of a known number of animals; inexperienced observers counted 43 percent. Caughley (1974) and Caughley et al. (1976) suggested that the best solution to the problem of observability in aerial censuses is to measure the magnitude of the biases that exist, and correct estimates accordingly. This paper describes an attempt to measure observability bias in an aerial census of deer in deciduous-coniferous habitat and to produce an accurate estimate of numbers.

STUDY AREA

The study was conducted in a 393 to 399 km^2 portion of the Superior National Forest (SNF) in Lake County, Minnesota lying northeast to northwest of Isabella. The area included parts of Townships 59, 60, and 61 North in Ranges 8, 9, and 10 West of the Fourth Principle Meridian.

The vegetation of the study area is mostly maturing coniferous-deciduous forest. Few unmixed stands remain except in lowlands, which occupy about one-third of the area and are dominated by white and black spruce (*Picea glauca* and *mariana*). Balsam fir (*Abies balsamea*), red pine (*Pinus resinosa*) jack pine (*Pinus banksiana*), aspen (*Populus tremuloides*), and birch (*Betula papyrifera*) predominate in the uplands. About 25 percent of the upland consists of red pine and jack pine plantations. Much of the area has been cutover since 1935 (Peek et al. 1976), and is still being logged on a small scale.

Deer had declined in the region from 1968 through 1974, and an area of more than 3,000 km^2 just north of the study area has been devoid of wintering deer since 1972 (Mech and Karns 1977). Some deer immigrate into the study area to winter, usually by December (Nelson 1977), but there is no evidence that deer resident in the study area emigrate in winter. Thus our winter estimates probably exceed the actual number of deer inhabiting the study area for most of the year.

METHODS

Our census technique involved two basic steps: (1) aerially counting deer in census plots, and (2) testing the observability of deer in test plots similar to the census plots. We conducted three censuses, from 7 December 1975 through 4 January 1976, from 25 January through 11 February 1977, and from 13 February through 3 March 1978. Maximum snow depths during the three censuses were 61, 46, and 73 cm, while minimum temperatures were -37C, -40C, and -35C. The counts were based on stratified random sampling with optimal allocation of sample plots, a type of sampling particularly applicable to populations with clumped distributions (Cochran 1967). Census stratification and plot allocation were based on aerial strip surveys of deer and tracks in transects .8 km apart, involving 7 hours of flying. Plots within high, medium, and low density strata were chosen at random. Several workers have used this design in estimating populations of big game animals and describe the technique in greater detail (Peek et al. 1976; Siniff and Skoog 1964).

Our censuses were made under clear to bright-cloudy light conditions at altitudes from 60 to 150 meters above ground from a Piper PA-18A-150 Super Cub aircraft. The Super Cub proved highly advantageous because of its maneuverability and ability to fly at low speeds and altitudes.

Both pilot and passenger (senior author) searched the plots intensively in a series of over-lapping circles such that each piece of ground was observed at least once. Whenever a deer was sighted, the pilot was requested to circle until the observer was satisfied that as many animals as possible were observed. Census plots were approximately 2.6 km^2 each with boundaries based on identifiable landmarks such as ridges or streams, and averaged 17 minutes each for completion. We censused 40 to 45 plots each year.

We used radio-tagged deer (Hoskinson and Mech 1976; Nelson and Mech in prep.) to test our observability bias in the census. Thirty radio-tagged deer with color-coded collars were available, ten in winter 1975-76, four in 1976-77, and 16 in 1977-78 (Nelson 1977). The collars did not seem conspicuous enough to increase the observability of the deer. Test plots of 1.3 to 2.6 km^2 containing radioed deer were located on maps by an impartial observer and a pilot other than the census pilot (Table 2). Test plots were then searched within the next few hours by the senior author without redio telemetry, using the same pilot, plane, and search techniques as in the counts. In several instances the same deer were used during different days but only if their locations changed between trials. The test plots were located in the same region as the census area, although not actually within the census area. Weather and cover variation among plots and tests was similar to that during counts. Thus we assumed that the proportion of collared deer missed in the test plots approximated the proportion of deer missed in the census plots. Correcting census data with the figures thus derived gave an estimate of the actual deer density.

RESULTS AND DISCUSSION

Deer were observed under forest conditions varying from open canopy to an estimated 80 percent closed canopy. In winters 1975-76, 1976-77, and 1977-78, 51, 55, and 69 deer were seen during the censuses. However, the low density stratum constituted an increasing proportion of the census area each year, from 62 percent in 1975-76 and 63 percent in 1976-77 to 79 percent in 1977-78. Furthermore, the number of deer seen in the low density stratum dropped from .16/km^2 in 1975-76 through .15/km^2 in 1976-77 to 0 in 1977-78 (Table 1). Therefore, when these densities are projected to the entire study area the mean number of deer seen actually decreased from .40 deer per km^2 in 1975-76 to .33 in 1976-77 and .20 in 1977-78.

The observability tests indicated that 56 percent of the deer were seen during the first winter, and 50 percent during the second and third (Table 2). Correcting the census results by multiplying them times the reciprocals of the observability figures for each year yields total estimates of .70, .66, and .40 deer per km^2 (Table 1).

The observability of collared deer remained remarkably constant between test days and between winters despite variable weather (Table 2). The results of the observability tests indicate that, with the intensive search method of counting deer under the conditions in our study, approximately half of the deer are seen.

To apply our technique for correcting aerial censuses of deer over large areas, we suggest that observability tests be made several times during the census, because ground and weather conditions can change throughout the census, and that deer observability be tested in different cover types, with separate correction factors applied for each type.

Although observability tests add substantial expense to a deer census, they increase the accuracy of the results considerably. Furthermore monitoring the movements of the radioed deer provides significant insight into seasonal migration patterns and distribution, phenomena that other deer census methods have failed to consider. Such insight puts census data into both seasonal and areal perspective.

It is not yet clear whether our census technique is sensitive enough to make precise year-to-year comparisons. However, it certainly is accurate enough to provide an excellent indication of gross deer density and to document the fact that in the present study area, deer numbers are exceptionally low.

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Table 1. RESULTS OF THREE AERIAL CENSUSES

	1975-76					1976-77					1977-78 1/				
	Area counted		Deer seen			Area counted		Deer seen			Area counted		Deer seen		
Density Strata	km²	% of stratum	No.	Per km²	Projected Total	km²	% of stratum	No.	Per km²	Projected Total	km²	% of stratum	No.	Per km²	Projected Total
High	50.8	41	40	.79	97.6	56.4	71	37	.66	52.1	72.0	88	69	.96	78.4
Medium	4.5	15	3	.67	20.0	18.2	26	11	.60	42.3	-	-	-	-	-
Low	49.5	21	8	.16	38.1	46.8	19	7	.15	36.8	33.0	11	0	0	0
	104.8			Total	155.7	121.4			Total	131.2	105.0			Total	78.4
				corrected factor 2/	x 1.77				correction factor 2/	x 2.00				correction factor 2/	x 2.00
				corrected total	276				corrected total	262				corrected total	157
				deer/km²	.70 3/				deer/km²	.66 3/				deer/km²	.40 3/

1/ Because of increased winter severity, deer were more concentrated, so there was no medium density stratum.

2/ From Table 2.

3/ Study area was 393 km² in 1975-76, 399 km² in 1976-77, and 395 in 1977-78.

BLE 2. RESULTS OF DEER OBSERVABILITY TESTS

st te	Weather[1]	Known Number of Collared Deer	Number Collared[2] Deer Observed	Percent Observed	Correction Factor[3]
nuary 8, 1976	Fair	6	3	50.0	
nuary 9, 1976	Good	10	6	60.0	
tal 1976		16	9	56.3	1.79
bruary 3, 1977	Fair to poor	4	2	50.0	
bruary 9, 1977	Good	4	2	50.0	
tal 1977		8	4	50.0	2.00
bruary 28, 1978	Fair	7	4	57.0	
rch 12, 1978	Good	3	1	33.0	
rch 15, 1978	Fair	6	3	50.0	
tal 1978		16	8	50.0	2.00

1/ Weather was considered poor when any of the following conditions prevailed; winds high, temperature below -28° C, cloud cover low, or snow falling. When temperature was above -10° C, winds were light or calm, cloud cover was light, and there was no precipitation, conditions were considered good.

2/ Number of radio-tagged deer observed using both pilot and passenger.

3/ Reciprocal of percent observed.

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